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JOURNAL

VOLUME 12, NUMBER 7 • JULY, 1956

Fast 48 to 64 Ounce Machine

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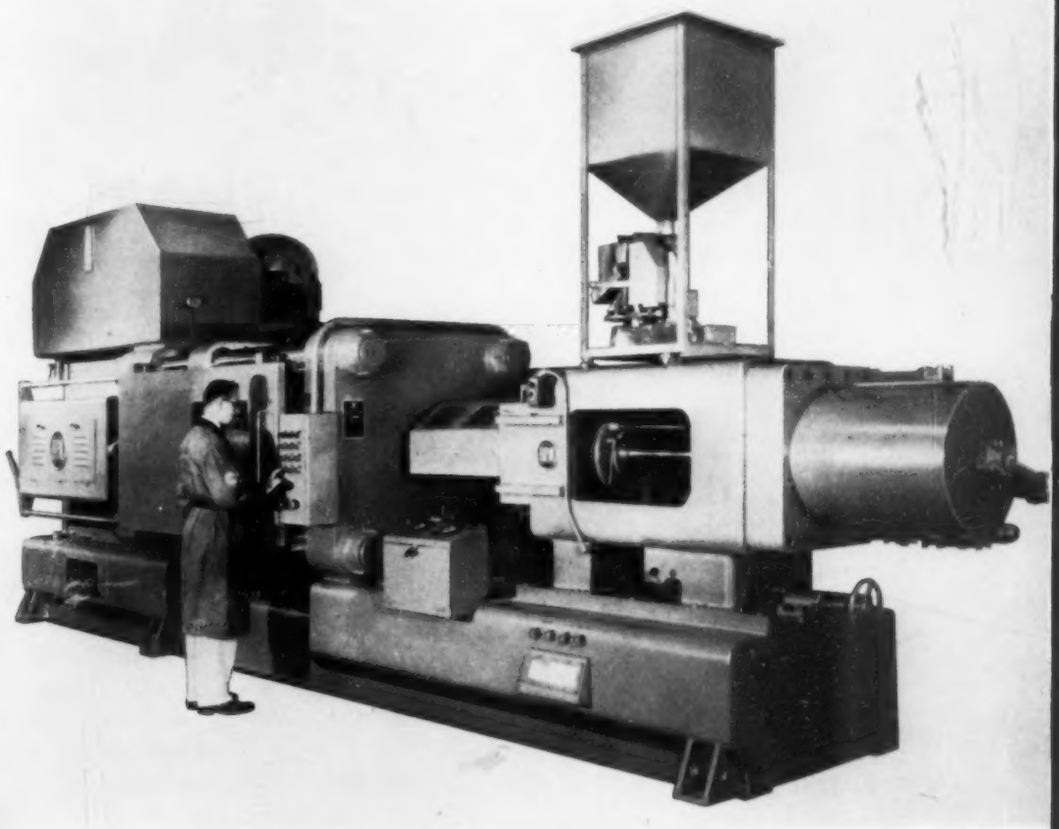
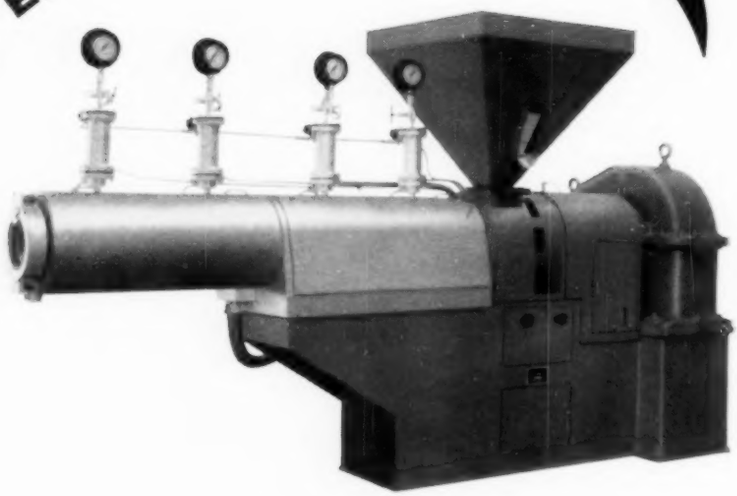


(Photo Courtesy The Hydraulic Press Mfg. Co.)

PUBLISHED BY THE SOCIETY OF PLASTICS ENGINEERS, INC.

Egan EXTRUDERS



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U.S.I. POLYETHYLENE PROCESSING TIPS

Vol. 1, No. 4

Molders Can Minimize Shrinkage

Shrinkage of injection molded items is often a troublesome problem for molders. In closures, and in components which are to become part of an assembly, excessive shinkage can be a major cause of rejects. The growing use of polyethylene for such parts has sparked molder interest in shrinkage control on items made from polyethylene resins.

While a certain amount of shrinkage is inherent in any process that involves cooling of a material from elevated temperatures, it is possible for injection molders to minimize the condition to acceptable levels.

In polyethylene, such control may be achieved by the right choice of operating conditions and by selection of a resin with characteristics to fit them.

Lower Temperatures Key to Less Shrinkage

Since shrinkage is a natural result of cooling, a main avenue of attack on the problem is to mold at lower temperatures. Here are some procedures that tend to reduce shrinkage:

Reduce barrel temperature and run a cold mold.

Use high pressure and long inject time to pack the mold as much as possible, short of causing the item to stick.

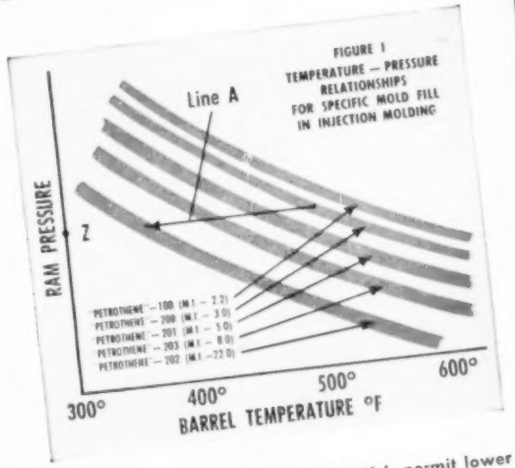
Allow longer dwell time. This helps to equalize temperatures throughout the mass so that cooling takes place at a uniform rate.

This point deserves further comment. Since the last material to flow into the mold is considerably hotter than the plastic at the extremity, a substantial temperature differential may still exist when the mold is opened. This uneven cooling results in non-uniform shrinkage which, in turn, causes the item to warp. Longer dwell time permits some equalization of this temperature difference and thereby keeps uniform the shrinkage that does occur. (The problem of warpage is discussed more fully in a previous issue of "Processing Tips". Write for a reprint if you missed it.)

High Melt Index Resins For Lower Molding Temperatures

Polyethylene resins with high melt indices can be a big factor in reducing shrinkage. In the first place, high melt index permits lower molding temperatures. This means less cooling, hence less shrinkage. At the same time, their higher flow characteristics permit tighter packing of the mold.

PETROTHENE 202 and 203 polyethylene resins are well suited to operating conditions for minimum shrinkage. The high melt indices of these resins permit reduction of injection temperatures by 70° to 130° for a given fill, cycle time and ram pressure. This is graphically illustrated by a set of curves for a particular mold:



Curves show how resins with high M.I. permit lower molding temperatures for a given pressure and fill. At pressure Z, a resin with comparatively low M.I., such as PETROTHENE 200, may require a barrel temperature of 500°F. Under the same conditions, PETROTHENE 203 requires 430°, PETROTHENE 202 only 370°.

Special Problem? Call on U.S.I.

In general, the suggestions outlined here will reduce shrinkage of molded polyethylene items. Some experimentation may be necessary, of course, to achieve a satisfactory result for your particular situation. In many cases, a switch to high-flow resins such as PETROTHENE 202 or 203, where these resins are satisfactory for the end-use, will permit operation at best conditions for minimum warp.

If the nature of your product creates an unusual problem, don't hesitate to call on U.S.I. for technical assistance. Well qualified Technical Service personnel stand ready to help you find a practical and economical solution.

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SPE JOURNAL

Vol. 12 July, 1956 No. 7

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A new anti-radiation suit that gives the wearer a grotesque "man from Mars" look is the latest application of versatile plastics.

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Despite its bulky appearance, the suit is exceptionally light-weight and permits the wearer complete freedom of action. Manufactured by the Snyder Manufacturing Company of New Philadelphia, Ohio, the outfit offers a high degree of safety from radioactive contamination, corrosive liquids, fumes, dust and bacteria.

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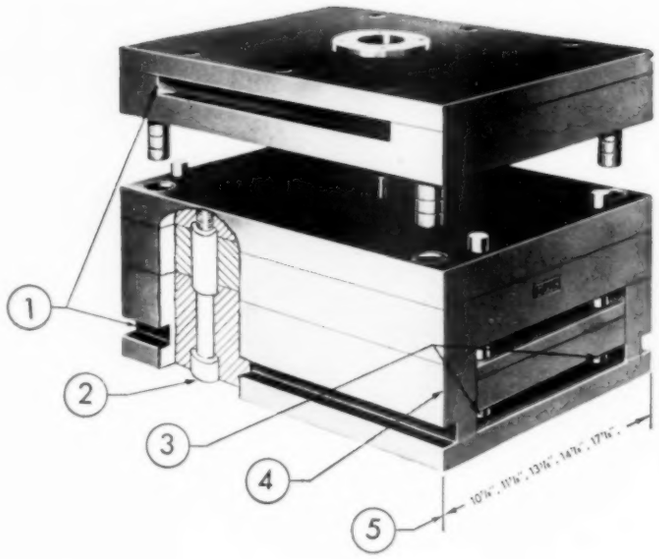

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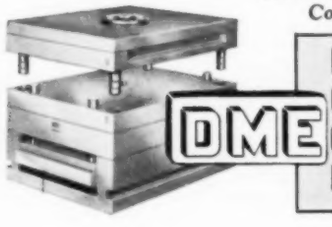

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● *For further information on* ALATHON *34 and 37, write to E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Department, Room 427, Du Pont Building, Wilmington 98, Delaware.*

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After initial experiments, a "cycle control" compression molder was constructed to mass-produce the speaker shell. Using DYLITE, the beads were "popped" to twice their original size by pre-heating, then poured into the mold for treatment under heat, moisture and pressure. "The finished product has a relatively dense skin. It weighs only six pounds *with* speaker; it's strong enough to be bounced without breaking. The beads inside form a soft, resilient wall, permitting the inner surface to vibrate as an independent membrane, isolated acoustically from the outer wall."

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AT RIGHT
Mr. Leonard Bonn holds a model of his "Bonn Sonosphere" speaker, produced with DYLITE polystyrene.

BELOW
One-half of a "Bonn Sonosphere" still in the compression mold. Made with DYLITE, the completed sphere is an ideal "hi-fi" sound baffle, weighing just six pounds, including speaker.

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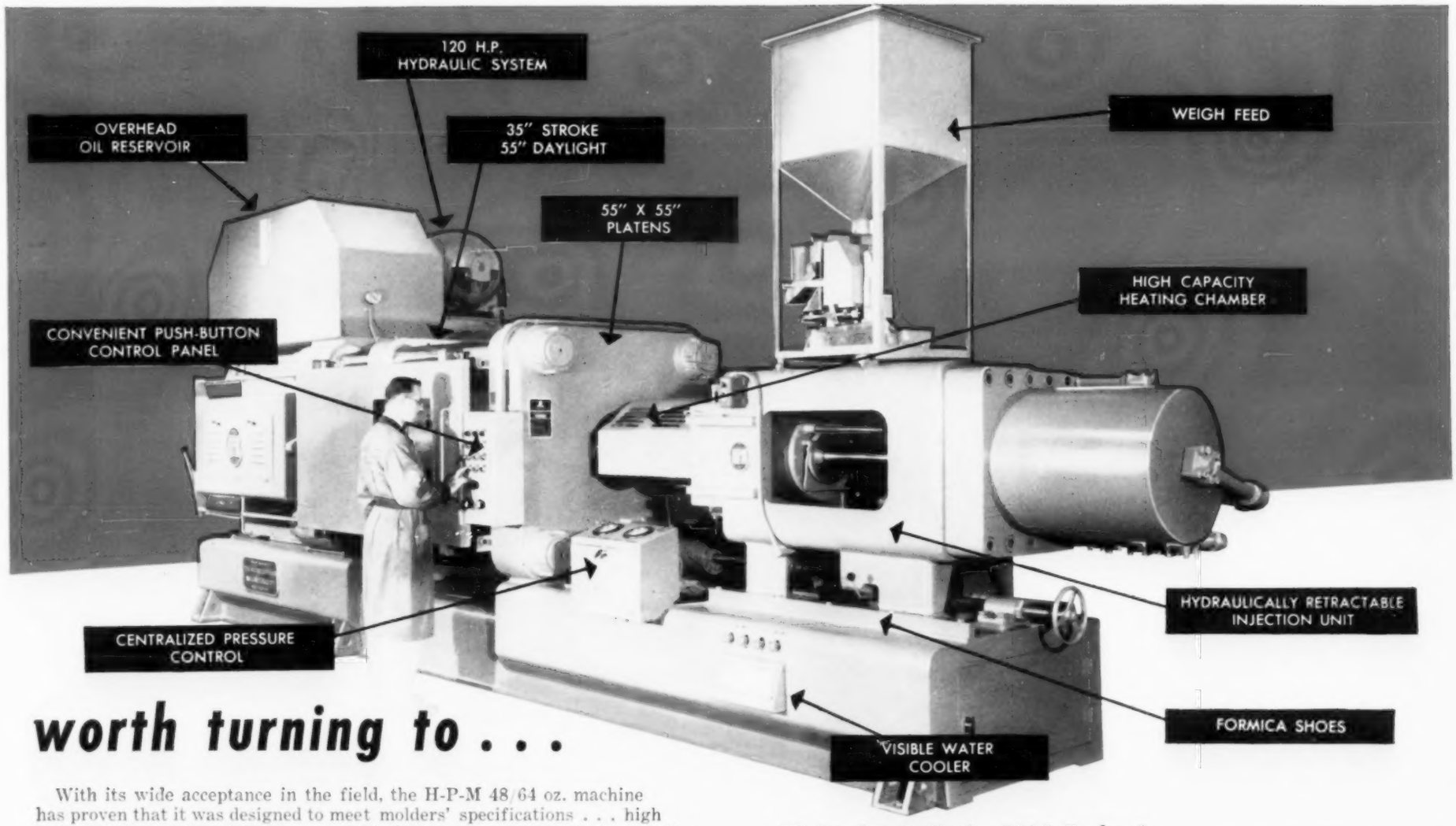

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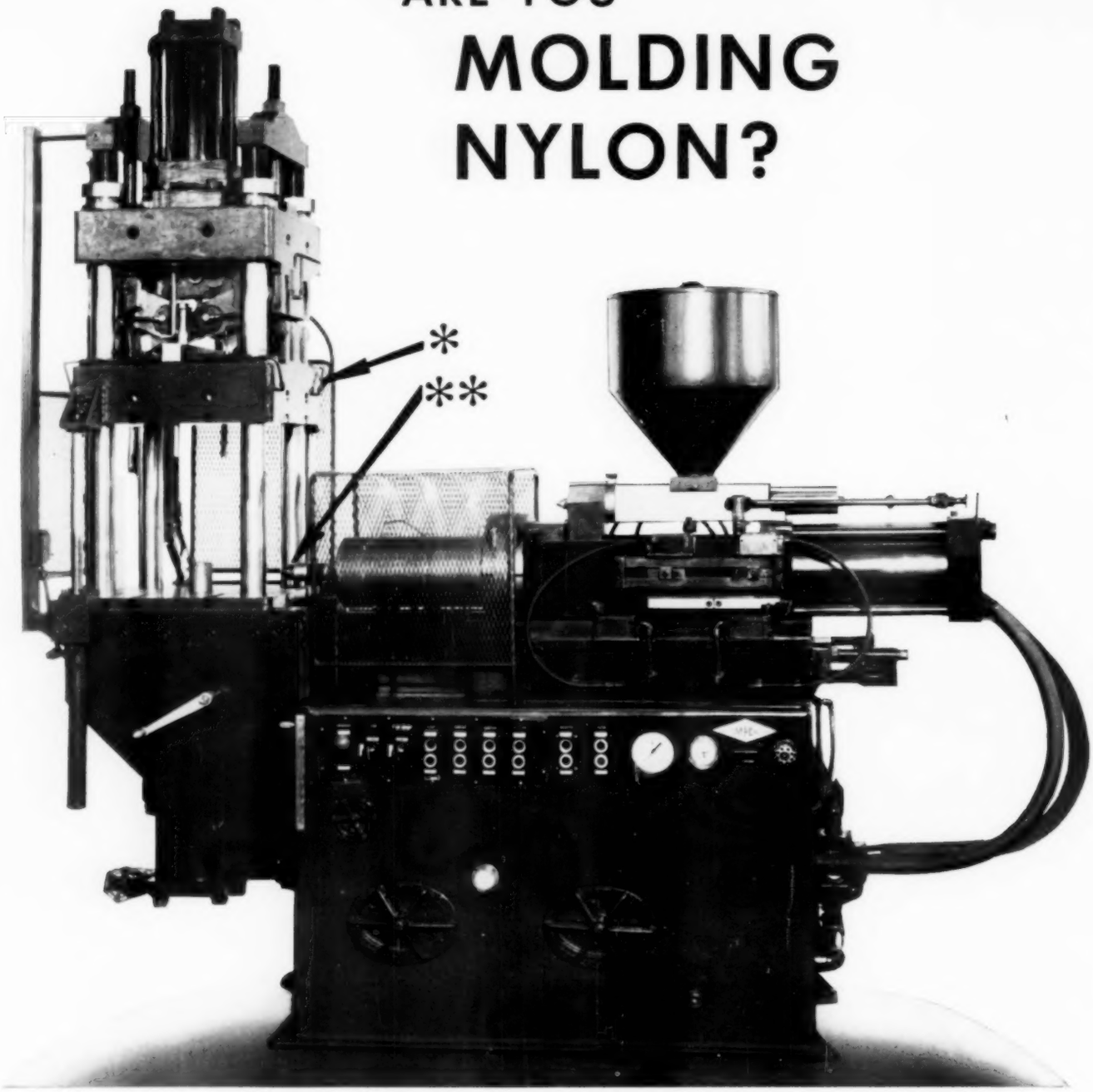

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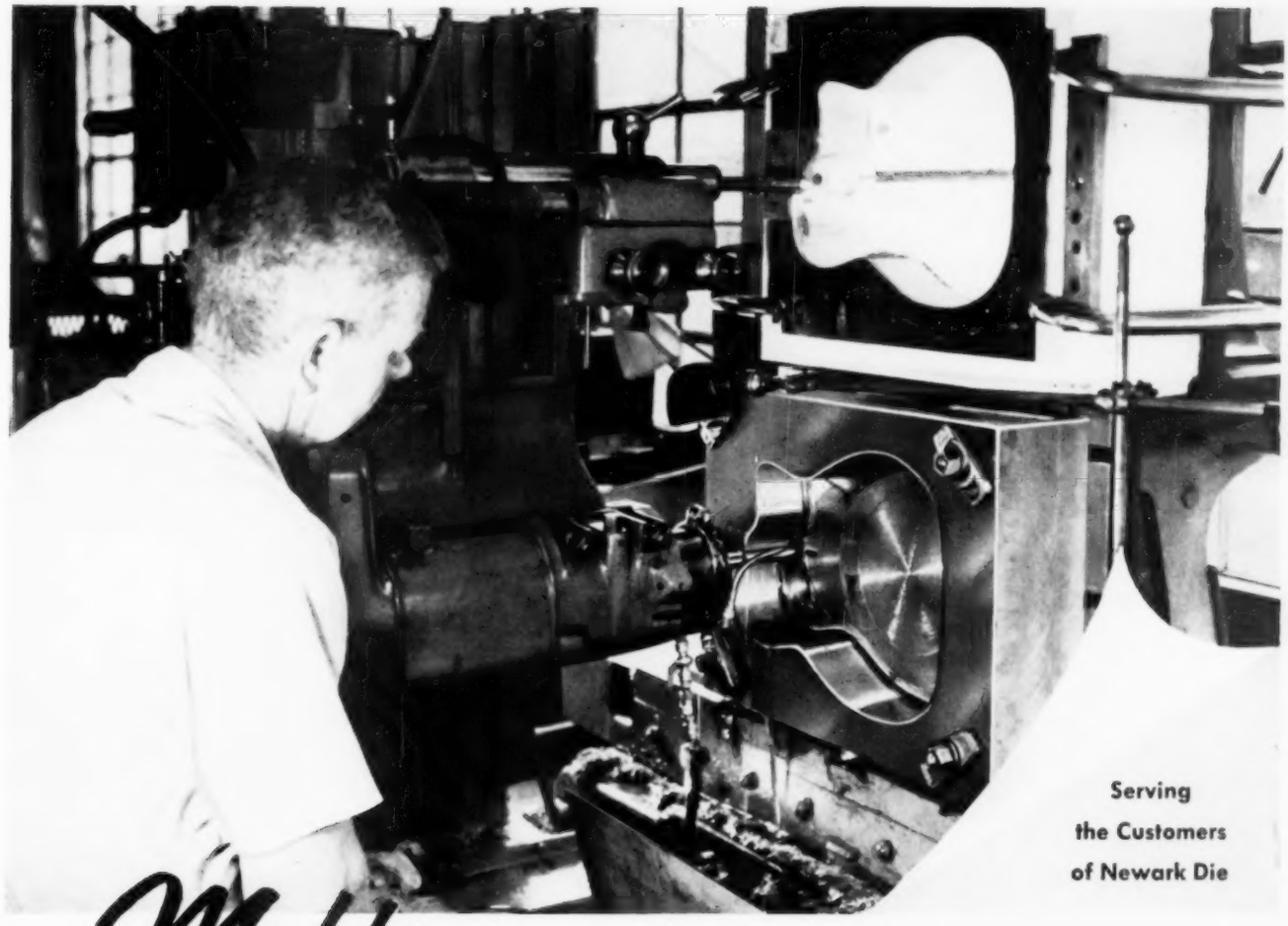

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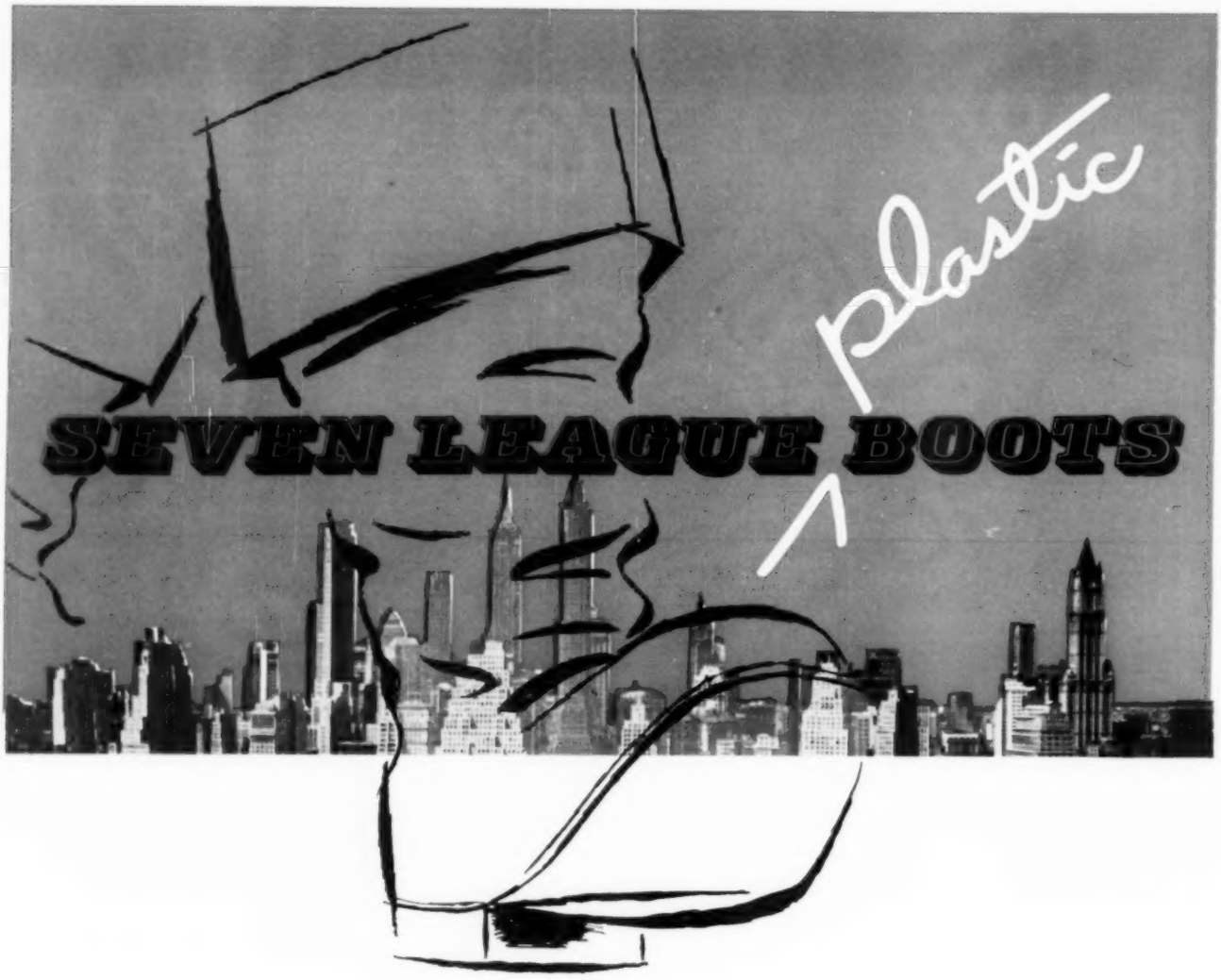

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The Effects of . . .

Explosions on Plastics

The behavior of materials under mechanical shocks is of interest in connection with the selection of materials for the construction of many devices which are to be subjected to loads of short duration.

The duration of shock loads under actual conditions varies from a few seconds to less than one ten-millionth of a second as shown in Figure 1. The loadings of shortest duration are associated with the impact of steel on steel and with the detonation of explosives. This paper presents some results on the behavior of various plastics materials when subjected to shock waves generated by the detonation of lead azide.

H. A. Perry, Jr.

U.S. Naval Ordnance Laboratory

DURING THE DETONATION of lead azide the pressure rises to some immense and unmeasurable pressure, practically instantaneously. The pressure then decays very quickly to a value of about 1,400,000 psi which persists for about 1/40th of a microsecond from the beginning during which time the reaction proceeds. Within ¼ of a microsecond from the beginning the pressure has decayed to about 350,000 psi, and in less than one microsecond the pressure has approached zero.

As a result of the explosion a shock wave moves away from the site with an initial velocity of about 12,000 feet per second. This shock wave has a sharp front and the initial pressures in the shock front are in excess of 1,000,000 psi.

On striking a solid surface, a large portion of the energy is reflected back as a compressive wave in the gases. The remainder of the energy enters the solid as a compression wave and traverses the material at a lesser velocity and amplitude, which are determined by the elasticity and density of the material. In traversing the material the velocity, amplitude, and sharpness of the shock wave may be reduced by spreading out and by internal friction within the material.

When the shock wave traveling within the material strikes a boundary of the solid with a material of lower product of density and modulus of elasticity, a portion of the energy is reflected back into the solid as a tensile wave. The remainder of the energy leaves the solid as a compression wave in the next medium. This loss from a solid to a dense, incompressible medium such as water is appreciable. However, the loss from a solid to air is usually insignificant. No mechanical energy can escape to a vacuum. The velocities, amplitudes, pulse lengths, and energy contents of the reflected and transmitted waves are dependent on the elastic constants and the densities of the two media as shown in Figure 2.

Due to losses to the next medium the tensile stress in the reflected front, while still near the surface, may be less than the compressive stress existing at that point in the material, and may be cancelled out by the compressive stresses. As the front of the tensile wave moves back and the tail of the compressive wave moves forward, the net tensile stress in the material increases to full value at a distance back from the surface equal to about ½ the pulse length in the material. In this interval the tensile strength of the material may be exceeded by the tensile stress and fracture may occur.

If the peak tensile stress in the reflected wave is only slightly greater than the tensile strength of the material, the fracture will occur at a distance back from the boundary about equal to ½ the pulse length. (1) The fragment then contains a large part of the pulse energy and is thrown away with considerable velocity. This phenomenon is known as spalling.

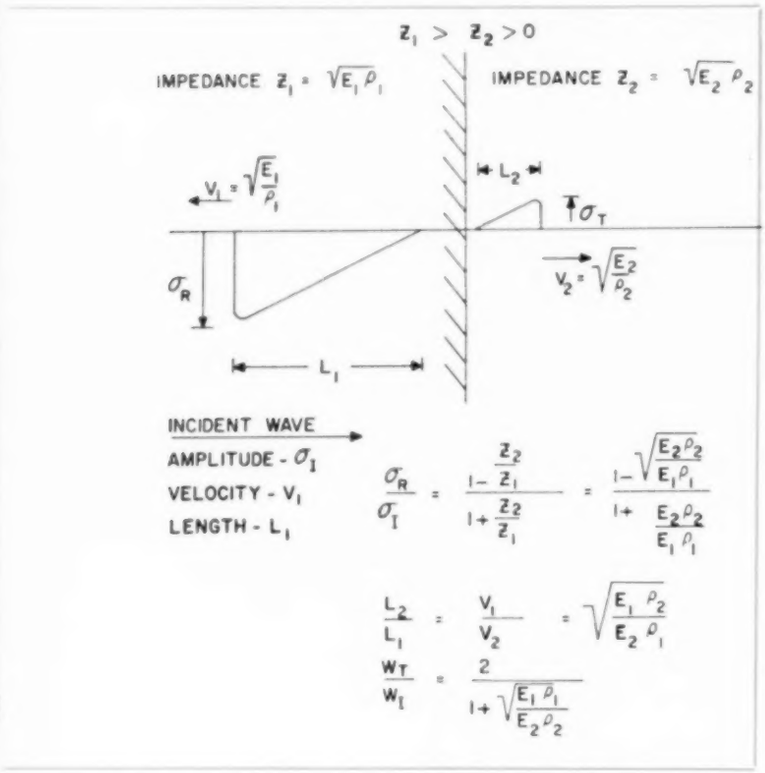
If the peak tensile stress in the reflected wave is greatly in excess of the tensile strength of the material the spall will occur nearer the surface. The remaining portion of the compressive wave which has not yet entered the zone of fracture collides with the new surface and is reflected as a new tensile wave, which may cause a second spall. This cycle may be repeated any number of times to produce successive spalls, each flying off with less velocity than the preceding spall, until the reflected tensile waves contain stresses less than the tensile strength of the material. It has been shown (2) that the number of spalls is equal to the first whole number smaller than the quotient σ/σ_c, where σ is the peak tensile stress in the first reflection and σ_c is the critical tensile strength of the material.

The tensile wave which retreats from the surface after the last spall may traverse the material without causing additional fractures, unless it should traverse another tensile wave which had been reflected from some other surface. In this region the stresses in the two tensile waves reinforce and add to each other. If the sum of the tensile

FIGURE 1

DURATION (SECONDS)	TYPE OF LOADING
5×10^{-2}	Parachute Opening
1×10^{-2}	Impact on Sand
5×10^{-3}	Impact on Water
2×10^{-4}	Impact of Steel on Steel
1×10^{-6}	Total Pulse, Lead Azide
2×10^{-8}	Reaction Time, Lead Azide
1×10^{-10}	Pressure Rise, Lead Azide

Figure 2. Characteristics of shock waves depend on densities and elastic constants of media.


$Z_1 > Z_2 > 0$
IMPEDANCE $Z_1 = \sqrt{E_1 \rho_1}$
IMPEDANCE $Z_2 = \sqrt{E_2 \rho_2}$
$V_1 = \sqrt{\frac{E_1}{\rho_1}}$
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σ_R
$V_2 = \sqrt{\frac{E_2}{\rho_2}}$
L_1
INCIDENT WAVE
AMPLITUDE - σ_I
VELOCITY - V_1
LENGTH - L_1
$\frac{\sigma_R}{\sigma_I} = \frac{1 - \frac{Z_2}{Z_1}}{1 + \frac{Z_2}{Z_1}} = \frac{1 - \sqrt{\frac{E_2 \rho_2}{E_1 \rho_1}}}{1 + \frac{E_2 \rho_2}{E_1 \rho_1}}$
$\frac{L_2}{L_1} = \frac{V_1}{V_2} = \sqrt{\frac{E_1 \rho_2}{E_2 \rho_1}}$
$\frac{W_T}{W_I} = \frac{2}{1 + \sqrt{\frac{E_1 \rho_1}{E_2 \rho_2}}}$

stresses in all of the waves traversing a point within the material exceeds the critical tensile strength of the material then internal fractures will occur.

The phenomena of spalling and internal fractures due to reflected shock waves are well known in metals (1) (2) and glass (3) (4) and have been the basis for intensive research in connection with the development of weapons and armor plate. Very little information exists however with regard to the effect of explosions on plastics.

Working with specimens of various shapes made of Perspex, a plasticized methylmethacrylate, Kolsky and Sherman (5) showed that the fractures produced by small charges of explosive in the transparent plastic are of very regular form, and can be accounted for in terms of the reflection of an outgoing pressure pulse at the free boundaries of the specimen. They also showed that the nature of the fracture under these conditions differed from that found in Perspex at less rapid rates of loading in that individual cracks are unable to propagate in the very short time of application of stress. They also discovered that no optical strains could be observed in the Perspex under polarized light even in the regions close to the fractures where the stress must have been nearly equal to the tensile strength of the material. They took this to indicate that at the very rapid rates of loading associated with the passage of stress waves no appreciable flow takes place in Perspex.

Landon and Quinney (6) showed that, during the propogation of a compression pulse into the tip of a cone, as in Figure 3, reflections from the sidewalls follow the compression pulse with amplitude AE/r^2, which increases rapidly as the tensile front approaches the tip. Kolsky and Sherman (5) also showed that the pulse lengths decrease logarithmically as the compression and tension waves enter the tip. Therefore, the material in the tip is subjected to larger and larger tensile stresses of shorter and shorter durations until a spall occurs.

Kolsky and Sherman, (5) using a 0.4 gram charge of lead azide on Perspex cones, demonstrated that incipient spalling occurs at the shoulders of the cones, that the reinforcement of reflected tensile waves on the axis of the cones produce internal fractures, and that the tip spalls with considerable velocity. This experiment has been reproduced by the author as shown in Figure 4. This cone was 4.75" long and 2" wide. The change of lead azide was 0.4 grams.

The author then undertook to evaluate the experiment as a method of test for the tensile strength of plastics under very suddenly applied loads, and to obtain comparisons at low, ambient and elevated service temperatures on materials which are used in ordnance.

Additional cones were machined from methylmethacrylate and rigid polystyrene bar stocks. These cones were made smaller than before and were 2.6" high and 1.25" wide.

Lead azide charges of various weights, 0.1, 0.2, 0.4, 0.8, and 1.6 grams, were pressed into aluminum cups, 0.015" thick, as shown in Figure 5. The cups were capped with thin aluminum disks and fitted into a hole in a cylinder of phenolic rod stock, facing an S46 squib. The base of the cups were mounted flush with the end of the phenolic cylinders.

The assembly was supported in precarious fashion in a hole in a light cardboard on a ring stand. The charge was detonated by the application of six volts to the squib. The cone and its fragments were recovered from the water in a beaker underneath by means of a cloth screen.

The plastic cones were preconditioned for at least one hour at various temperatures, −65°F, 73°F, and +160°F. Cones removed from the conditioning chambers were fired within thirty seconds from the time of their removal. Five replicates of each plastic were fired at each temperature and charge weight.

In these tests, and in fact in all subsequent tests, the geometrical similarity of deformations and fractures within sets of replicates was so marked as to permit the pre-

Figure 3. Compression pulse in a cone is reflected from sidewalls.

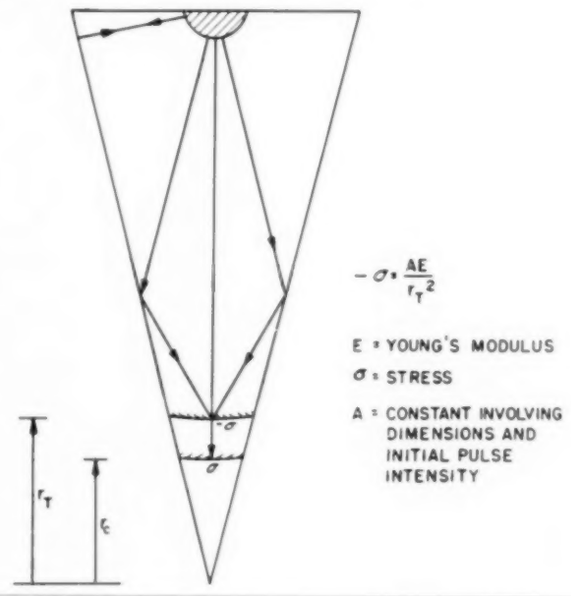
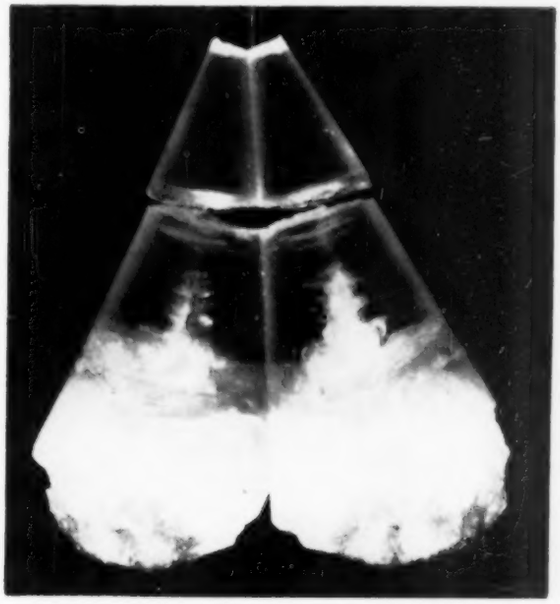


Figure 4. Effect of detonation on lucite 2" diameter. Explosive charge 0.4

Effect of detonation on Lucite 1.25" diameter. Explosive charge 0.2 gram.



paration of diagrams. Not all combinations of charge weight and temperature were tested for reasons of economy.

It was noted immediately that the extent of damage is very greatly increased by a moderate reduction in the size of the specimens, in that the shoulders of the 1.25" diameter methacrylate cones were shattered by charges as small as 0.1 grams, whereas the shoulders of the 2.0" diameter cones were not shattered by a 0.4 gram charge.

It was also noted that the resistance of the methacrylate to fracture was dependent on temperature. Based on the rule set forth by Reinhart, (2) the ratio of the tensile stress to the tensile strength is equal to, or greater than, the number of spalls plus one. Assuming that the tensile stress in the wave is independent of temperature then the ratio of the tensile strengths would be in range of $(N_1 + 1)/N_2 + 1) = 3/2$ or $4/3$. On this basis, it would seem that under these conditions the methacrylate at $+160°F$ is 3/2 as strong as it is at $-65°F$. It was noted that the fractures were similar in appearance at all temperatures. However, the sites of the explosions were depressed at $+ 160°F$ and also to some extent at room temperature, but at $-65°F$ they were not.

The polystyrene cones were then fired with somewhat different results. It was apparent immediately that polystyrene is not brittle, and in fact will flow extensively under suddenly applied loads at elevated temperatures less than its second order transition temperature. The absence of spalling at the tips and shoulders at elevated temperatures was taken as an indication that a large amount of energy of the detonation was expended in deforming the plastic at the site of the explosion, and that the shock wave radiating from the site was weakened thereby. At low temperatures, polystyrene resembled methylmethacrylate in brittleness and resistance to fracture. At room temperature the polystyrene spalled twice, as against once for the methacrylate, even though it had deformed noticably at the site of the explosion. On this basis, it would appear that at room temperature the polystyrene is weaker than methylmethacrylate under shock loading.

At this point, a set of single cavity molds was built to permit the manufacture of cones using other compression, transfer and injection molding materials. It was realized that residual strains at the gates might be of considerable magnitude and that the mode and extent of the fracture of the cone might be distorted by the gate. However, our greatest interest was in the behavior of the tips. We also wished to obtain symmetrical flow in the mold. Accordingly, the injection and transfer molds were gated on the axis at the future site of the detonation.

Additional cones were then manufactured using the materials listed in Figure 6. The materials were selected on the basis of their relative importance in projects underway at that time. Injection molded nylon was being used with considerable success in shock applications, particularly in thin sections when quenched in a cold mold. Other applications with thick sections of molded or cast nylon had not been successful due to brittleness. This was attributed to the excessive crystallization which always occurs in thick sections due to the slow cooling of thick sections. No scheme was suggested with which to obtain quenched, amorphous nylon moldings in sections as thick as those to be found in the cones. Accordingly, nylon was not included in these tests. Other materials such as the rigid vinyls, the numerous modified styrenes, the high

Figure 5. Diagram of method of preparing the explosive charge set-up.

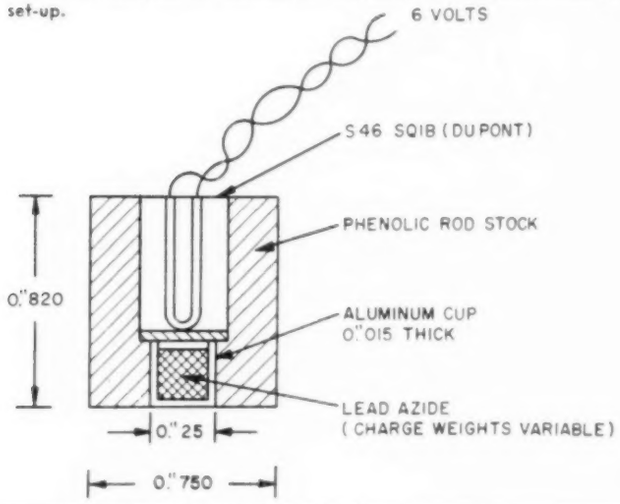


Figure 6. Materials used in explosives test.

THERMOPLASTICS
- Polyethylene — Low Density — High Molecular Weight
- Cellulose Propionate — Plasticized
- Ethyl Cellulose — Plasticized

CAST RESINS
- Polyester — Flexible Type
- Polyester — Rigid Type
- Polyester, Rigid + Chopped Rovings

PHENOLICS
- Two Step + Wood Flour
- Nitrile Modified + Cotton Flock
- Nitrile Modified + Chopped Fabric
- Two Step + Tire Cord

density polyethylenes, the fluorocarbons, the epoxies, the polyamide modified epoxies, the diallyl phthalates, the melamines, the silicones and other plastics which are now of considerable current interest or importance were not included for reasons either of economy or of availability at the time.

The results on low density, high molecular weight polyethylene are noteworthy in that polyethylene is plastic and was cratered at the site of the explosion even at low temperatures. At elevated and room temperatures the cratering was extensive. Spalling cracks developed at the shoulders which with one exception did not detach. In this one group of five replicates at room temperature the spalls were all ring like in shape. Counting the number of spall cracks at 0.2 gram charges the polyethylene is not significantly weaker at +165°F than at room temperature. Spalling occurred at −65°F indicating that the material is brittle under shock loadings at a temperature somewhat above its second order transition temperature of −95°F. It was also noteworthy that the tips were not spalled under any condition.

Factors in Spalling

Several factors seem to combine to preclude tip spalling. These include:

a. attenuation of the compressive wave due to extensive plastic deformation at the site of the detonation

b. loss of energy to the air at the sides of the cone because the low density and low Young's modulus of the material

c. attenuation of the shock waves traversing the material because of internal friction.

The concept of high internal friction in polyethylene under shock loadings is supported by the observation that plastic flow at the site did not prevent spalling by reflected waves at the shoulders which were near to the site, but that no spalling could be induced at the tips which were far from the site. In this connection it is conceivable that the polyethylene could first have been heated temporarily by adiabatic compression to a condition of fluidity, in which state the attenuation of the waves might have been appreciable, and later have been cooled by rarefaction to a condition of brittleness.

The results with cellulose propionate show that the material is similar in behavior at elevated temperatures to polyethylene except that the tips spalled at high energies. From this we may infer that the attenuation of shock waves through cellulose propionate is somewhat less than in polyethylene. At room temperature the shoulders spalled but not the tips. At low temperature the material behaves like methylmethacrylate and polystyrene. Some unknown property of the material prevents multiple spalling. Instead, the spall site moves up the cone as the energy is increased.

Cellulose Resistant

Ethyl cellulose shows exceptional resistance to plastic deformation and spalling. The craters were very shallow at all temperatures. The tips spalled at low temperatures but the shoulders did not. From this we may infer that the material is very transmissive to shock waves and that the strength of the material could only be overcome when the amplitude of the tensile waves had been amplified by the focusing effect of the conical shape of the specimen. Considering the low attenuation of the waves and counting the spalls it appears that ethyl cellulose is at least twice as strong at low temperatures as polymethylmethacrylate or polystyrene.

Turning now to the polyesters we find that the supposedly flexible material is brittle at low and high temperatures and is demolished readily by shock waves. Incidentally this material was so flexible at room temperature that the tips could be bent readily by thumb pressure. However, the material here is quite glassy under high impact.

The rigid polyester is even more brittle and weak under high impact than the flexible grade.

The use of glass fibers in a polyester resin does not prevent plastic flow or fracture, but aids materially in holding the part together after fracture. Based on the incidence of cracking under shock loads, glass filled polyesters are inferior to ethyl cellulose except possibly at low temperatures, at which temperature about an equal amount of cracking occurs in both substances.

A general purpose wood flour filled phenolic is resistant to cratering at any temperature, and is about equal in shock resistance to methylmethacrylate.

The modification of phenolics with nitrile rubber and with cotton flock increases the toughness of phenolics under shock loads even at low temperatures. This improvement is increased by the use of chopped fabric instead of cotton flock.

The addition of chopped tire cord to an unmodified phenolic greatly increases the resistance of the phenolic

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Orders of Merit

Resistance to Plastic Flow At Site of Impact	Cracking Resistance Under Shock Loading	Retention of Shape After Shock Loading
Tire Cord Phenolic	Tire Cord Phenolic	Tire Cord Phenolic
General Purpose Phenolic	Ethyl Cellulose	Rubber Modified Phenolic
Ethyl Cellulose	Rubber Modified Phenolic	Polyester & Chopped Roving
Rubber Modified Phenolic	General Purpose Phenolic	Ethyl Cellulose
Polyesters	Cellulose Propionate	Cellulose Propionate
Polymethylmethacrylate	Polyethylene	Polyethylene
Polystyrene	Polymethylmethacrylate	Polystyrene
Cellulose Propionate	Polystyrene	General Purpose Phenolic
Polyethylene	Polyester-Flexible	Polymethylmethacrylate
	Polyester-Rigid	Polyester-Flexible
		Polyester-Rigid

The Engineering of ...

Purchased Molds

J. C. O'Brien
Shaw Insulator Co.

One of the plastics industry's most firmly established relationships is that of the molder and the mold supplier. All plastic molding companies, even those with their own mold-making facilities, have occasions to purchase molds from outside sources from time to time. Most molders obtain the great majority of their molds in this way. This paper will concern itself with some of the problems associated with sharing the burden with an outside tool source, and examine some of the methods being used to minimize these problems. It will emphasize that the purchase of a mold does not necessarily include the purchase of a complete engineering service. It will suggest that the best interests of the plastics industry, and its customers, are served when engineering responsibility is retained by the molder.

TO BEGIN WITH, it must be remembered that the independently operated mold shop is usually doing business with many different molders at the same time and cannot be expected to keep abreast of all the various standard practices and special requirements of each molder. These variations are due to differences in equipment, specialization in certain types of applications and individual preferences as to molding techniques.

Some molders find it to their advantage to place the bulk of their work with one supplier and thereby become such an important customer that the supplier is inclined to take more than a normal interest in the molder's problems. Other molders divide their work among several suppliers to gain delivery advantages, make maximum use of available skill, and to gain the protection of the American system of open competition. In either case, the molder must stay in close contact with the supplier throughout each phase of each job.

This close contact is of mutual benefit to the molder and the mold supplier. The supplier is busy building molds, in the course of which he stays alert to the latest mold construction methods. The molder, on the other hand, is busy "living" with the molds and is in a better position to evaluate the latest molding techniques, material behavior, and molding equipment capabilities. Thus, in the planning and construction of a new mold, each has an important contribution to make. By frequent exchange of information, the moldmaker learns how new techniques in mold construction perform in production, while the molder learns new methods which he may profitably apply to his planning on forthcoming jobs.

Through close contact, the molder also performs an important service to his customer and to his supplier, as well as to himself, by helping to insure that the delivery schedules will be met.

The molder, through his engineering department, performs his role most efficiently when he treats this molder-mold supplier relationship as a separate important engineering function until a definite procedure is organized and established. Contact with the mold supplier is best maintained through one engineer in the molder's organization, to whom this responsibility is delegated. Exceptions are taken only with great caution to avoid repetitious or, worse, conflicting information passing back and forth. Obviously, the amiable spirit of cooperation necessary for a good relationship does not thrive on confusion.

This one engineer insures that the particular needs of all other interested people in the organization are being attended to during the construction of the mold. (To list a few—the set-up men for proper and easy installation, the preform department for use of standard preforms where possible, the tool repair shop for ease of maintenance, the finishing department, cost department, and that special department whose job it is to inform the customer when a delivery promise is about to be broken). It is virtually impossible to coordinate these particular needs and keep everyone informed without the use of proper records and schedules. Several examples will be described as we go along.

Stages in Engineering

Running briefly through the various steps in engineering a mold, we come first to the design stage. A molder with sufficient design work to keep one or more designers busy on a full time basis, or who can arrange assignments so that a designer's fill-in activities can be safely curtailed when a mold must be designed, often finds advantages in providing his own drawings, especially if his work is specialized or his molding techniques are unconventional. It is borne in mind, however, that good mold design requires concentrated effort and should be given the benefit of the designer's undivided attention. This is too important a phase of any project to risk errors or omissions.

Another advantage for the molder providing his own drawings is the possibility of obtaining a better mold delivery promise. Long delivery promises are often due to a backlog of design work and the difficulty of planning a schedule until the drawings are completed and approved.

Vendor-supplied drawings have the advantage of being favored by the man who has to use them. The simple reason is that he is more accustomed to the form and style of his own designer. Method of dimensioning, placement of

views and significant notes by a designer who is familiar with his work habits, gives the toolmaker a feeling of confidence. At the same time, if the toolmaker has any questions, it is an advantage to have the designer nearby to discuss them. Drawing errors are often caught and eliminated in this way.

Vendor Drawings

When using vendor-supplied drawings, the molder will furnish basic information before expecting the designer to proceed. Some of the important points, covering many types of molds, are as follows:

1. Type of mold.
2. Number of cavities.
3. Size and type of press.
4. Layout of press (if not of standard make).
5. Type of plastic material.
6. Shrinkage of material.
7. Desired layout of cavities.
8. Size and number of preforms to be used.
9. Diameter of transfer plunger.
10. Size of runners, gates, and orifice diameter.
11. Location of gates, vents, ejectors, and parting lines.
12. Preference as to hobbed, cast, or machined cavities.
13. Preference as to type of steel.
14. Function and description of special features such as side-action or loose details.
15. Type of heating or special cooling.

When requested, the mold supplier will use standard tracing forms supplied by the molder. This may be important to the molder's filing system.

An indispensible checklist which every purchaser of molds can develop is one for mold design. It is a list which never is really complete because whenever a problem arises which can be relieved through some improvement in general design, the checklist is pulled out and a new entry is made. This system helps to avoid falling into the same old traps over and over again.

Following is a fairly general checklist and is not intended to include points of personal preference. Checklists in actual use certainly do include these points also.

CHECK LIST FOR MOLD DESIGNS

1. Check mold for press for which it is intended:
   a. Ejector arrangement.
   b. Daylight.
   c. Clamping.
   d. Steam or water connections.
   e. Height and diameter of transfer cylinder.
   f. Overall dimensions of the mold.
   g. Clamping and transfer pressures.
   h. Ease of loading material.
2. Double check for reverse views.
3. Ejector travel.
4. Strength of ejector bar.
5. Provide buttons under the ejector bar.
6. Check dimensions of insert pins.
7. Tool tolerance on all critical part dimensions.
8. Leader pins should enter before any other part of the mold.
9. Provide clearance holes for telescoping pins and cores.
10. Leader pin centers must be unsymmetrical about at least one mold centerline.
11. Bushings should be locked in position by a plate, shoulder, or set screw.
12. Reduce land area to a minimum when practical.
13. Keep as many core pins and larger portions of butt pins as possible in ejector half of the mold.
14. Positive return pins for ejector bar.
15. Check number of ejector pins.
16. Provide ejector pins at bottom of deep pockets.
17. Check to see if pick-ups are needed.
18. Relationship between pick-ups and ejector pins should be designed to eliminate any distortion of pieces during ejection.
19. Check steels used in mold parts.
20. Mold plates should be heavy enough to prevent distortion.
21. Harden plates which are subject to wear.
22. Maintain as much mold support as possible under cavities and landed area.
23. Maintain a safe distance between edge of steam or water lines and screws, dowels, or cavity and force recesses.
24. Check number of steam or water lines and course of steam.
25. Maintain adequate distance between steam inlet and outlet centers and clamping bolt slots.
26. Mold to be stamped with proper identification, mold and part numbers on top and bottom halves.
27. Provide insulation between mold and any side cylinders or micro switches.
28. If the design permits, grind vents from the cavities.
29. Check for easy dis-assembly of mold.
30. Molds which cannot be easily lifted to have tapped holes in front and rear of top and bottom halves for the use of eye-bolts.
31. Molded parts should bear the trademarks and cavity numbers when permissable.
32. When the force is on the ejector side of the mold, provide vented ejector pins to prevent excessive vacuum between part and force.
33. Stripper plates to be mounted so they do not ride free of guide pins.
34. Provision for temperature control and or thermometer when required.
35. Design loose cores to fit the mold one way only.
36. Provide proper identification of loose cores.
37. Make loose cores as light as possible.
38. In tray type molds, cavity numbers to be in the tray side of the mold.
39. Check draft.
40. Check shrinkage factor.
41. Design mold to accept insert loading fixtures if they are to be used.
42. Leader pins to be on the force side if possible, and should be longer than the force projection, to prevent damage to force.
43. Depth of part must be less than ½ mold opening to be able to remove part.
44. Check anticipated pattern of material flow.
45. Check transfer plunger with respect to pressure, stroke, depth of transfer cylinder, and loading space for the material.
46. Check position of the transfer gate to prevent washing away of pins and inserts.
47. Design gate position with a thought to finishing the part.
48. Provide removable sprue bushing when possible.
49. Call for chrome plating when required and specify whether it will be done before or after sampling.
50. Check to see if the latest issue part drawing was used.

Within a few days after the design drawings are finalized, the mold supplier can plan his schedule. This may be a rather nebulous thing in most mold shops, however, because in order to plan his work for most efficient use of his men and machines, the mold supplier must resort to a certain amount of give and take among several molds

Figure 1

MOLD DELIVERY BREAKDOWN
JONES MOLDING COMPANY

MOLD # 10789

DESCRIPTION 10-cavity compression mold

PURCHASE ORDER # F 2377 DATED Jan 18, 1956

TOOLMAKER'S JOB # _____ NAME OF TOOLMAKER _____

MOLD IS SCHEDULED TO BE DELIVERED ON April 12, 1956 (DATE)

THIS CONSTITUTES A CONSTRUCTION PERIOD OF 12 WEEKS. TO AID US IN FOLLOWING THE PROGRESS OF THIS TOOLWORK, THE TOOLMAKER WILL PLEASE FILL IN THE FOLLOWING BREAKDOWN BY MARKING DOWN THE NUMBER OF THE WEEK DURING WHICH EACH PHASE OF THE JOB WILL BE COMPLETED.
(TOOLMAKER MAY KEEP ONE COPY)

DESCRIPTION OF WORK	WEEK OF COMPLETION Est.	Actual
DESIGN COMPLETED		2nd Week
ROUGH MACHINING COMPLETED		
HUB READY FOR HARDENING		
HOBBING COMPLETED		
FINISH MACHINING COMPLETED		
FRAME COMPLETED		
POLISH, SOFT		
HEAT TREATING		
FITTING		
FINAL POLISHING {Chrome-plating, yes ☐ no ☐}		
FINAL ASSEMBLY COMPLETED.	12th Week	

PLEASE RETURN ONE COPY TO JONES MOLDING COMPANY

for several customers. Too often the real planning is done by assessing the situation about 2 or 3 weeks before the due date and then planning the balance of the work. Occasionally, the due date is lost sight of until it arrives.

In spite of the difficulty of planning each move as soon as the design is completed, there are several milestones along the way to mold completion which can be plotted in advance to insure that some slip-up in the middle of a job will not go undetected until the eleventh hour.

The Engineer Can Help

The engineer can help to plot these milestones by presenting to the mold supplier a simple form which lists them, and provides a space for him to fill in the date or the number of the week during which that part of the job is expected to be completed. The use of a carbon provides that each can keep a copy.

When the passing of each milestone is observed by a telephone call or, preferably, a visit to the supplier, much is accomplished toward insuring prompt delivery. Normally, the mold supplier welcomes this opportunity to share his "memory burden" with the molder. (See figure 1).

When it is customary for many molds to be in construction at the same time, usually with several suppliers, a composite schedule is maintained for the benefit of interested departments in the molder's organization. This schedule is reviewed every week or so to add new projects as they are initiated, drop off the ones which are completed, and provide up-to-date delivery information. Such a schedule proves invaluable as a means of communication between the engineer and other interested departments as well as a "memory jog" to all interested parties.

Routing of copies depends upon the molder's organizational setup, but some equivalents of these departments are included on the list:

1. Sales, for customer information.
2. Production, for scheduling of open press time.
3. Set-up men, for general preparedness.
4. Purchasing, for coordinating delivery of molding material, inserts, etc.
5. Tool room, for mold check and for completion of fixtures and gages, if any.
6. Accounting, for passing of invoices and preparation of billing.
7. Management, for aid in keeping a finger on the pulse of new business and general activity.

This schedule contains enough information for easy identification of each project and columns for the delivery date promised to the customer, the original delivery date promised by the mold supplier, and the latest delivery estimate, if different from the original. Space is also provided for pertinent remarks. (See figure 2.).

The Completed Mold

When a mold is completed and ready to be delivered, we would like to assume that conscientious follow-up had precluded the possibility of any "loose ends" remaining. Such is seldom the case, and so a final checkup is made, preferably before the mold is delivered, and certainly before the mold is set in the press.

It is sometimes possible, when inspecting the completed mold, to spot a miscalculation or an oversight—which was not so apparent in the earlier stages. In addition, the workmanship and adherence to specifications are checked.

Some of the points looked for are:

1. General appearance, especially molding surfaces and runner system.
2. Ease of operation of moving parts.
3. Cutoff of all butting surfaces.
4. Flash clearance and cleanout slots where required.
5. Eye bolt holes.
6. Mold and cavity identification.
7. Steam or water leaks. Also size and accessability of ports.
8. Spare parts to be furnished.
9. Cavity vents.
10. Pickups when required.
11. Hardness of cavities & forces.
12. Press dimensions.
13. Provision for temp. control or thermometer.

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Figure 2

SCHEDULE OF MOLD WORK IN PROCESS

Copies: Sales, Production, Molding, Purchasing, Tool Room, Accounting, Gen. Mgr.

CUSTOMER	PART	MOLD DESCRIPTION	MOLD SUPPLIER	DELIVERY PROMISES			REMARKS
				TO CUST.	FROM VENDOR (original)	FROM VENDOR (latest)	

A Potting Compound and Mold for Precision Pottings

William H. Crandell
Frederick S. Bacon Laboratories

The object of the work covered by this paper is the development of a potting compound and design of a potting mold to produce precision pottings in which the control of final dimensions and properties of the completed unit are critical.

POTTING IS NOW becoming standard practice in the electronic fields. Some of the advantages to be gained by potting or encapsulation are as follows:

1. Rigid location of components in relation to one another.
2. Increased electrical resistance between adjacent components.
3. Increased resistance to humidity.
4. Increased resistance to vibration.
5. Increased chemical resistance.
6. Improved heat transfer.

The particular problem with which we were concerned was the potting of a microsyn stator for use in a gyroscope.

The microsyn stator (Figure 1) has four poles on which are mounted wound copper coils. These coils are connected by means of wires to a male plug connector which facilitates making the electrical connections after the unit is inserted into the gyroscope.

By potting the microsyn, we felt that the over-all performance of the gyroscope could be improved because:

1. The individual coil windings and the coils themselves would be rigidly held in a given location from which they could not shift, thus preventing variation in the electrical output of the microsyn during use.
2. Dirt and other foreign matter could be trapped in the unit and subsequently transferred to the assembled gyro.
3. The microsyn would be protected from damage should it be accidentally dropped.

Development of the Potting Compound

The properties of a potting compound may be varied, depending on the end use of the potted unit. Potting compounds can be rigid or flexible, filled or unfilled. They can be color-coded for easy identification of the completed units. However, one thing is usually required of all compounds, and that is that the material be relatively fluid to allow complete impregnation of the item to be potted.

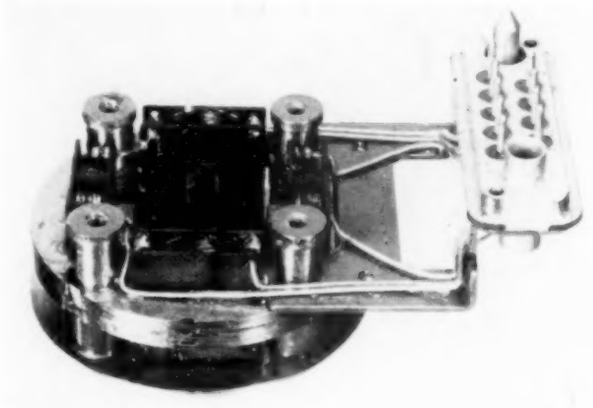
In our application, certain specific requirements had to be met. The cured compound must not be cracked by the stresses set up from thermal expansion and contraction of the various constituents in the microsyn when the unit is cooled to -70°F or heated to $+200^{\circ}$F. The compound should be resistant to the solvents used to wash the gyroscope parts before and during assembly, and should be resistant to flow under load at gyro operating temperatures so that the potted parts remain in position. In addition, no gaseous by-products should be evolved by the compound during prolonged heating. Such products would condense within the gyroscope, resulting in a shifting of the delicate balance of the unit.

Considering all the above points, an epoxy resin, rather than a polyester resin or a phenolic resin, was chosen as the base material from which a compound could be developed.

The polyester resin was ruled out because of its weakness and tendency to degrade at elevated temperatures and its high shrinkage during cure. The latter would render it more susceptible to cracking during temperature cycling because of the stresses set up during curing. The phenolic resins were not considered suitable for our application because of the volatile products given off during polymerization.

Consideration had to be given to the prevention of cracking of the epoxy resin by stresses set up by the differential expansion and contraction of the metal and plastic microsyn parts during thermal cycling. This cracking could be eliminated by modification of the resin with a liquid polysulfide rubber, producing a flexible product, which would be capable of absorbing and distributing the stresses. The cracking could also be eliminated by reducing the expansion coefficient of the resin so that it approximately matched that of the metal parts.

Figure 1. A Microsyn Stator



Since flexible potting compounds might allow movement of the potted parts relative to one another, it was decided to develop a rigid compound having a coefficient of expansion close to that of the potted metal parts by adding inert fillers. Many fillers are available for this purpose. Among them, to name a few, are metal powders, silicas of varying particle size, including glass beads and sand, and calcium carbonates. Of the above, the silicas and the calcium carbonates offer the least tendency to separate from the uncured resin because of their low specific gravity.

Next, consideration was given to the type of the curing agent to be used. Both acid-type and amine-type hardeners are used with the epoxy resins. Since the acid-type hardeners usually require heating to dissolve in the resin and since the resin-acid systems must be cured for relatively long periods at elevated temperatures, our efforts were concentrated on the more versatile amine curing agents.

Piperidine, one of the least active of the amine hardeners, was selected as the curing agent. Being a liquid, it decreased the viscosity of the resin when mixed. In addition, it produced a compound which has a fairly long pot life at elevated temperatures.

After selection of the basic materials for study, several formulations were made. The compositions of these formulations are given in Table I.

All the compounds were made by mixing the filler and the epoxy resin and passing three times through a three-roll paint mill. After mixing, the resin was warmed to 212°F, the curing agent added, and specimens cast into test tubes under vacuum. The resin was cured, removed from the test tubes, and machined to 7/16" diameter rods, 4" long. These rods were then tested using ASTM Procedure D696-44 to determine the coefficient of linear expansion. As was expected, the increased filler concentration resulted in a lower coefficient of linear expansion. It was noted that, during machining, formulations containing silica fillers dulled carbide tools, whereas the calcium carbonate-filled compound was easily cut and did not dull the carbide cutting tool.

It is also interesting to note that more of the large particle size fillers can be incorporated in the resin without increasing the resin viscosity beyond a workable limit.

There appears to be an optimum particle size from the standpoint of viscosity and of settling. For example, the 1240 silica, which has approximately the same specific gravity as that of the finer calcium carbonate filler, settles badly. However, the calcium carbonate filler does not settle significantly.

The particular calcium carbonate selected is a carefully-graded product having a particle size range of 5 to 15 microns. The particles are not so large that they will settle from the uncured resin before cure, thereby causing stratification and a resultant variation in the expansion coefficient of the potting. However, the particles are big enough so that the viscosity of the mixture is at a minimum.

No attempt was made to increase the amount of calcium carbonate filler above the 200 PHR (parts per hundred parts of resin) level shown in Table I because we felt that the formulation had a coefficient of expansion which was sufficiently low for our use.

The physical properties of the calcium carbonate-filled epoxy are given in Table II. Note that the properties after an eight-hour cure at 212°F are adequate for most commercial uses. If the ultimate in chemical resistance is required, an additional cure of forty hours at 300°F is given.

Some explanation at this point is required relative to the variance of catalyst concentrations shown in Tables I and II. At first, we found that the catalyst concentration required to reach the same state of cure as evidenced by the solvent resistance varied with each batch of resin. We have had to use as high as 12.5 PHR of piperidine to obtain adequate cures. However, during the past year the resin batches have not varied and we find that 7.5 PHR of piperidine is now adequate.

Mold Design

The requirements to be considered in the design of an ideal potting mold are; the necessity of complete impregnation of the item to be potted, maintenance of precise positioning of parts during potting, and the need for precise control of the dimensions of the completed unit. There should be no shrink marks on the surface of the resin nor should there be any need for machining of the resin after potting. The latter can be a costly operation and in our particular case would produce fine adhesive dust which would have to be removed prior to assembly of the potted microsyn in the gyro.

TABLE I
Effect of Fillers on the Coefficient of Expansion of Epon 828

Compound Number	Composition	Parts by Weight	Particle Size of Filler	Coefficient of Linear Expansion in./in. °F. x 10^5	Remarks
1	Epon 828	100		4.1	Fluid at room temp.
	Piperidine	6			Very fluid at 212°F.
2	Epon 828	100	2 - 4 microns	3.6	Not pourable at room temp.
	Celite Superfloss	30			Very viscous at 212°F.
	Piperidine	5			
3	Epon 828	100	124 - 246 microns	—	Rather fluid at room temp
	White Sea Sand	140			Very fluid at 212°F. Sand
	Piperidine	5			settles rapidly at room temperature.
4	Epon 828	100	99.5% less than 43 microns	2.3	Very viscous at room temp.,
	1240 Silica	140	68% less than 10 microns		pourable at 212°F. Filler
	Piperidine	6			settles noticeably after 1 hour at 212°F.
5	Epon 828	100	5 - 15 microns	1.7	Viscous at room temp.
	Calcium Carbonate	200			Fluid at 212°F. Very
	Piperidine	5			slight settling after 1 hour at 212°F.

To eliminate surface shrink marks, it was decided to use a transfer-type mold so that it would be possible to keep pressure on the compound during cure. Thus, as the material increases in viscosity and decreases in volume during polymerization, more resin is forced into the mold cavity to fill the void produced by shrinkage.

Aluminum was selected as the mold material because its coefficient of expansion was close to that of the potting compound. Because of this, when the mold was cooled, the part did not shrink around inserts making it difficult to eject. The aluminum was coated with a 1½ mil coating of Teflon as a release since epoxy resin adheres to most metals. We found that the life of the Teflon coating could be increased ten-fold by use of a coating of wax release before each potting. A high melting point microcrystalline wax, Crown 1035, Petrolite Corporation, Ltd., was used. Carnauba or Damar Wax probably would have been equally effective.

The mold had two parts: the potting reservoir and the mold or force. The reservoir (Figure 2) consisted of a ¾" wall thickness 5¼" I.D. cylinder approximately 3" high. The reservoir was sealed at the bottom by a plug and silicone rubber O-ring. Bolts through the reservoir base plate held the cylinder wall and plug in position.

The mold or force (Figure 3) was made in two parts (Figure 4). The lower part contained the actual mold cavity. The outer wall of the lower part was recessed to hold a silicone rubber O-ring. The O-ring prevented leakage of resin between the force and the reservoir wall. Inserts in the mold cavity were all bolted in place from the underside, the bolts recessed, and the holes plugged. One point regarding the bolted inserts; in order to prevent resin from flowing under the inserts during potting, thus making ejection of the parts difficult, the underside of the insert was recessed, leaving approximately a 1/16" land around the outside edge of the insert base. When bolted to the mold, enough force was exerted against the land to pull the metal into the Teflon release film, insuring a positive seal.

TABLE 2

Physical Properties of the Low Coefficient of Expansion Potting Compound

Formulation	Parts by Weight
Epon 828	100
Calcium Carbonate (5 - 15 microns)	200
Piperidine	7.5

Cure—8 hours at 212 °F.
Coefficient of Linear Expansion in./in. °F.—1.7 x 10^{-5}
Evolution of Volatile Matter on Heating—None
Flow Under a 15 lb. Load for 24 Hours at 250°F.—3%

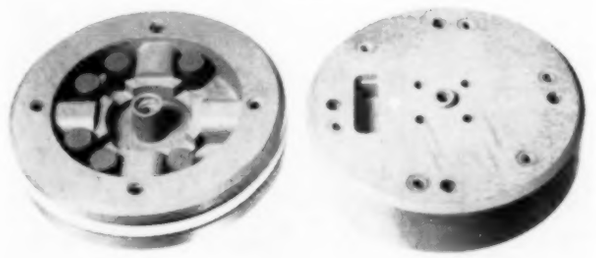
Effect of 24 Hours Immersion in Solvents at Room Temp.

Carbon tetrachloride	Resin unaffected
Perchlorethylene	Resin unaffected
Trichlorethylene	Resin slightly softened
Freon 113	Resin unaffected
Alkazene 42	Resin unaffected
R-200 Gauge Fluid	Resin unaffected
Toluene	Resin unaffected
Methanol	Resin slightly softened
Acetone	Resin slightly softened
Methyl ethyl ketone	Resin slightly softened

Figure 2. Potting Reservoir—Exploded View

Figure 3. Potting Mold Assembled

Figure 4. Potting Mold—Two Halves



The upper part of the mold was shown alongside the lower part in Figure 4. The four holes closest to the center hole were for mounting the microsyn stator. Four equally spaced holes near the periphery of the mold and the one hole in the center were for bolting the mold together. The other six holes on the periphery of the upper mold half were for ejection screws. Their use will be explained later. The large recessed hole in the upper half of the stator mold was for the plug connector.

Figure 5. Assembled Mold Preparatory to Potting

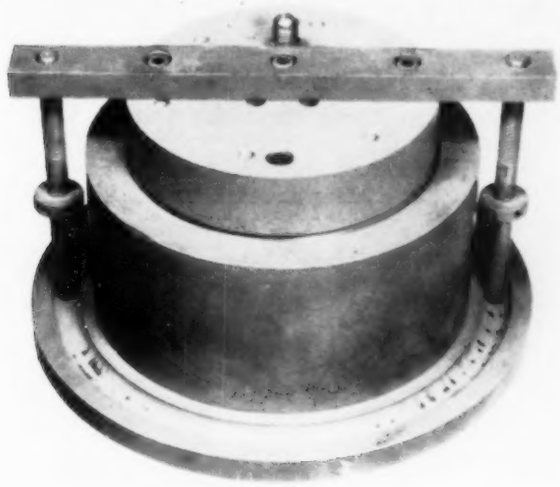
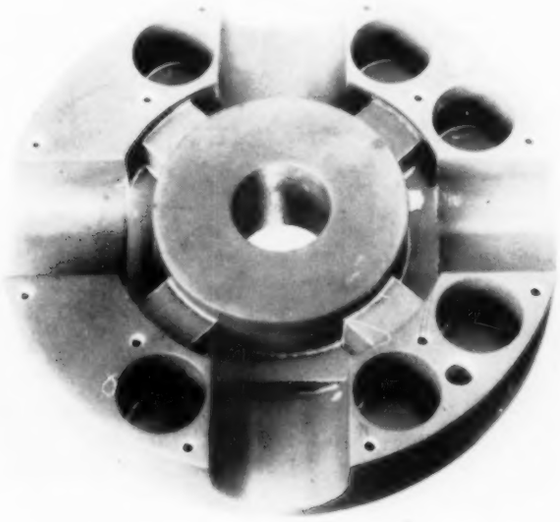


Figure 6. Bottom View of Potted Microsyn



Loading the Mold

Preparatory to loading the mold, 5 mil Teflon gaskets were placed over the four mounting posts on the microsyn. A 15 mil silicone rubber gasket was placed on the lip of the plug connector. The stator was inverted and placed in position on the upper mold half. Machine screws were inserted through the mold into the four mounting holes in the microsyn. Two 0-40 machine screws were inserted through the mold and screwed into the plug connector. Next, an alignment fixture was positioned on the mold to locate the center of the microsyn. With the alignment fixture in place, the mounting screws and plug connector screws were tightened.

The alignment fixture was removed and the two halves of the mold bolted together.

Potting Procedure

In the process of potting, the resin, previously warmed to 212 F., was catalyzed and poured into the reservoir which was also at 212 F. The reservoir was then placed on a hot press platen set to maintain a temperature of 212 F. The mold was placed in position in the top of the reservoir cylinder (Figure 5) and the outlet line connected to a vacuum system through a trap. The thumbscrews extending from the bar on the top of the mold were adjusted to keep the bottom of the mold approximately $\frac{1}{4}$" above the top of the warmed resin. The unit was then evacuated at $\frac{1}{2}$-1 mm. Hg. absolute pressure. At this point both the resin and the stator were being evacuated. This was found to be necessary in order to remove dissolved gases and air bubbles from the resin and also to remove the air in the potting cavity. After a suitable period, usually ten minutes, the thumbscrews were turned slowly allowing atmospheric pressure to force the mold downward into the reservoir, thus introducing resin into the mold cavity. As soon as the resin was seen in the glass trap near the exit hole on the mold top, the lowering was stopped and the evacuation continued for five minutes to remove any residual air. The thumbscrews were then completely loosened and the vacuum released. The mold was then pressed into the reservoir, using light pressure (500 lbs.) until more resin flowed out of the mold. The pressure was released, the vacuum fitting replaced with a pressure-tight fitting, and 30,000 lb. total pressure applied to the unit in the press for four hours at 212 F.

The pressure used, approximately 1000 p.s.i., forced the resin into the coil windings and compressed any air bubbles remaining in the resin. The compressed air dissolves in the resin. Since there is excess resin in the reservoir under pressure, it can flow into the mold cavity, eliminating any voids or shrink marks.

After four hours at 212 F. the mold was cooled. The bar across the top of the mold and base plate of the reservoir was removed. The mold, polymerized excess resin, and reservoir base plug were then pushed from the reservoir cylinder walls. The excess resin and base plate were taken off the mold. The bolts fastening the mold halves together were removed and ejector screws inserted into the upper portion of the mold. These ejector screws screwed into the upper half of the mold and turned against the lower portion, ejecting the lower mold half and leaving the potting attached to the upper part of the mold.

After the screws holding the potted microsyn and plug connector were removed, the potting can easily be removed from the mold by hand. The potted microsyn is shown in Figure 6.

Summary

Addition of 200 PHR of calcium carbonate of carefully controlled particle size (5 - 15 microns) to an epoxy resin with piperidine as a hardener produces a potting compound which does not stratify during cure and has good fluidity at 212 F. The compound when cured has a coefficient of linear expansion of 1.7 x 10^{-5}/F. The coefficient of expansion can be varied by regulation of the amount of filler added. The cured units potted with this resin are resistant to cracking during cycling from −70 F. to +200 F., have good chemical resistance, and produce no volatiles on heating.

Precision pottings having carefully controlled dimensions, no shrinkage, and complete impregnation of the item potted can be made using a modified transfer-mold. The mold is made of a metal having a coefficient of expansion similar to that of the potting compound in order to allow easy ejection of the parts from the mold. A Teflon coating on the mold is recommended as a mold release.

Acknowledgment

Acknowledgment is gratefully made to the Instrumentation Laboratory at the Massachusetts Institute of Technology and the United States Air Force, sponsors of this work at the Frederick S. Bacon Laboratories.

A Radically New Press and Mold

. . . . for Mass Production

. . . . of Large Plastics Shapes

A radically new type of press and mold capable of mass production of large plastic shapes by a process which can produce void-free reinforced fibre glass moldings with equipment costing less than that used in any other method has been developed. Plans to build the presses and molds and sell and license use of them to plastic fabricators in this and other countries are being made.

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The press-mold combination makes possible production of reinforced plastic structures of practically unlimited size and depth of draw. The equipment developed also enables the user to achieve close dimensional tolerances and uniform physical integrity throughout a structure, no matter how large. Heretofore, void-free moldings have not been possible in rapid, matched die production.

Thus, while the new technique is the equivalent in principle of employing matched metal dies, it is free of the physical limitations inherent in tool cost and production by the matched metal die method and makes the fabrication of large and complicated plastic shapes economically possible.

A battery of four of the new press-mold assemblies has already been built and has gone into production of automobile tops for one of the "big three" automobile companies. The tops, of reinforced plastic, have an impact resistance much greater than that of the conventional steel top.

Another product being turned out is a reinforced plastic bathtub for the home trailer industry. These tubs have the hard impervious finish and other characteristics of the conventional tub now in common use, at only a fraction of the weight of the traditional product.

The presses used to produce the automobile tops and bathtubs are of 120-ton capacity, are fully automatic, and operate with a one-inch power stroke. They weigh only one-fifteenth as much as the stamping presses used in the metal trades for comparable production, require no deep foundations and can be readily moved from one location to another.

Fully automatic presses of the same type as those of 120-ton capacity now being employed at the Toledo plant and employing the short power stroke technique can be made available up to 2500-ton capacity.

During a three year effort to produce porcelain-like bath tubs from fiber glass reinforced plastics, deficiencies in production equipment and method then accepted as good practice in the industry brought the program to a halt.

During this period, approximately 8,000 bath tubs were manufactured and delivered to the mobile home industry for installation in home trailers. The experience gained during this manufacturing effort focused attention on production problems which, if not overcome, would have made it impossible to produce bath tubs competitive in price and quality with the steel or cast iron product. These difficulties and problems were as follows:

1. MATCHED STEEL DIES AND PRESSES.
   - A. The high cost of dies and presses. (Several sizes and right and left hand models are necessary).
   - B. The impracticability of achieving required part thickness accuracy in large steel dies.
   - C. The need for cycling die surface temperature for the mold-coat application.
   - D. The uncontrolled occurrence of voids in back of the mold-coat.
   - E. The difficulty of controlling the glass content in the preform over areas of different part thickness.
   - F. The need for cleanliness and positive ventilation in the press area.

2. HAND LAY-UP.
   - a. High degree of operator skill required.
   - b. Difficulty of controlling part thickness and cure time on rapid production schedules.
   - c. The difficulty of obtaining shiny mold surface on any but steel dies.
   - d. The uncontrolled occurrence of voids in back of the mold-coat.
   - e. Mold-coat accelerator required, with attendant short pot life, for spraying unheated molds, or the use of a catalyst gun with proportioning difficulties.
   - f. Yellowing with age of highly accelerated mold-coat mixtures.

To overcome the above difficulties, new designs of presses and molds were conceived, enabling the use of a new molding technique. Full scale proto-type equipment was built and operated with excellent results. Subsequently, four large presses and five molds of the new design were built and put into commercial operation in a new plant in Toledo, Ohio. Results from the new equipment and process have met expectations in every way.

Basic features of the new equipment are as follows:

Molds.

Mold construction is based upon the forming of stainless steel sheet to the shape required for one die surface. This sheet is heated as a simple electrical resistance with a unique provision for obtaining uniform current flow, despite the depth of draw of the part. A synthetic elastomer is vulcanized to the back of the sheet to provide insulation and to allow for differential contraction and expansion between the sheet and its supporting structure. The supporting structure consists of aluminum filled epoxy resin (high heat distortion point) heated to 200 degrees Fahrenheit by an imbedded water circulatory system. The epoxy sub-structure is, in turn, supported by a structural steel member designed to control deflection within close limits under operating pressures. The mating die is cast to a high temperature wax layup on the steel surface, with special techniques for controlling the effect of thermal distortion and shrink during the casting process. It is this control that produces accuracy of part thickness. This epoxy casting is, in turn, supported by structural steel again to minimize deflection during operation. The dies are self aligning upon closure, thereby eliminating the necessity for this function in the press mechanism.

MOLDING DATA FOR BATH TUB

1. **Wall thickness. 0.1 inch at sides and 3/16 inches around the rim.**
2. **Cure time. Cure time is five minutes.**
3. **Catalyst. The catalyst is 1-1/2% of benzoyl peroxide in the gel coat and 1% of benzoyl peroxide in the laminating resin.**
4. **Molding pressure: The molding pressure is about 100 lbs. per square inch.**

Press.

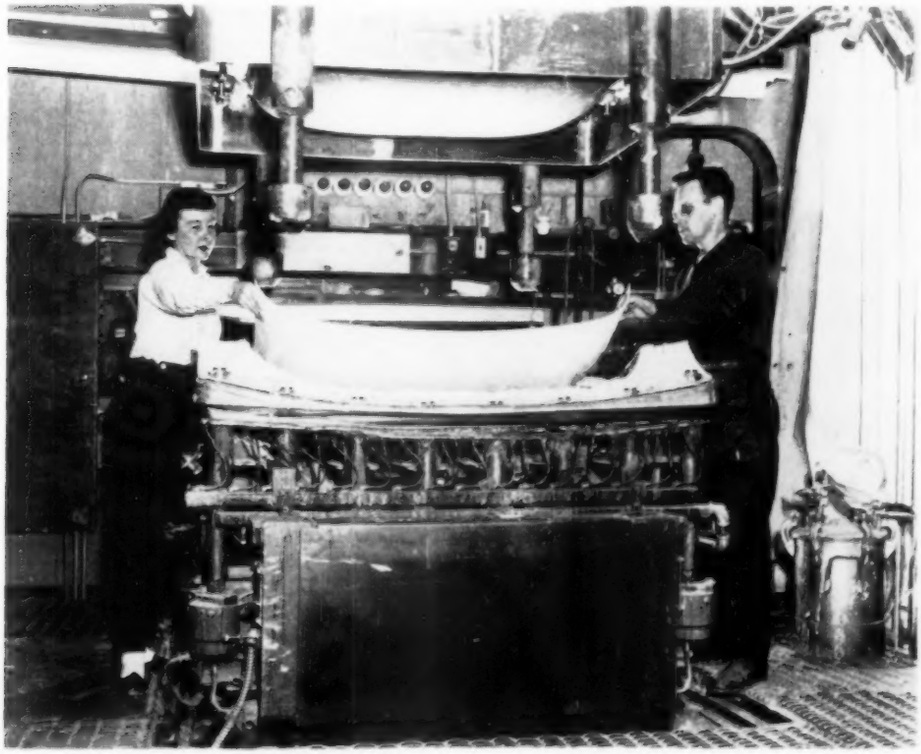
The dies are closed and opened by a unique type of press of 120 ton capacity with only a 1" power stroke actuated by a rubber bag. The press "daylight" is limited only by the height of the ceiling. The upper die is raised or lowered to the point of power stroke application by a conventional electric hoist. The entire press mechanism weighs approximately 4 tons. It is made of structural iron without any close tolerances. The press is constructed of demountable members and may be operated on any factory floor without special foundation. It is bolted together in a simple fashion, which makes it virtually portable. The press operation is completely automatic, with push button control. Platens of the presses in operation are 40" x 60" and may be operated up to 100 lbs. per square inch, with an adjustable rate of power application.

Process.

The polished stainless steel surface of the male bath tub mold (for example) is mold-coated with pigmented polyester resin to provide the shiny bath tub surface. Be-

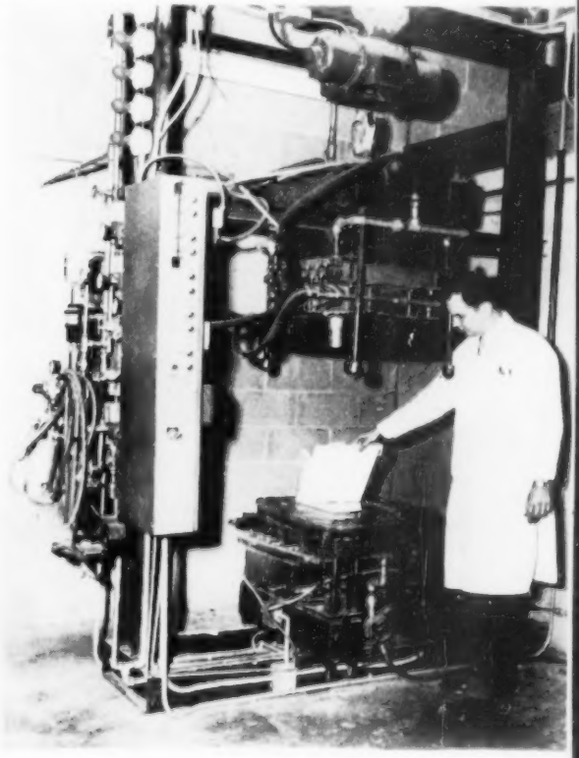
Car Top Mold

Mold coated car tops are currently made at the rate of five per hour. The upper mold, or plug, is high distortion point epoxy resin and the lower mold is surfaced by a stainless steel skin. The vacuum seal and baffle are readily apparent.



Test Press

A press and mold for making 12" x 12"' flat panels are exact counterparts of the larger production units. Control of molding variables can be set on a completely automatic system for experimental work.



cause the temperature of this surface may be raised or lowered within a fraction of a minute, the mold-coat is sprayed on at a temperature just below that at which styrene would be driven off. After the mold-coat has jelled, which takes a few seconds, the temperature is not turned up until the preform and resin have been applied and the mold is closed. The temperature is then raised to give cures comparable to those obtained with matched steel dies. With the stainless steel surface temperature variable up to 350 degree Fehrenheit, mold-coats of several different types of plastics can be applied.

Another unique and vital part of the process is the application of vacuum to the molding cavity during the period of closure by reduction of the air pressure in the cavity. A slight amount of styrene is vaporized and exhausted, thereby reducing the partial pressure of air to almost zero. Water vapor and air dissolved in the resin and absorbed in the surface of the glass fibers is also removed. When the part fills out and the resin reaches the cut-off bars, the closing pressure collapses styrene vapor voids in the resin and a void-free part is produced. The removal of air and water vapor also increases rate and degree of cure.

The vacuum system described above should not be confused with the use of vacuum with a bag or between rigid molds in such a way that atmospheric pressure forces mold closure, thus preventing the build-up of any appreciable vacuum in the mold cavity. In order to apply adequate vacuum to the resin charge, the dies must be held apart within close proximity and vacuum of the required amount applied to the sealed cavity. Vacuum bag process, or application of vacuum to obtain closure of two rigid molds by the action of atmospheric pressure, does not accomplish this function.

Preforms.

Because wrinkles and resin-rich areas from unequal distribution of glass greatly reduce the value of a bath tub, it was necessary to find a precise method to preform glass fibers for even distribution through the part and in the proper ratio to part thickness in sections made larger to provide strength where most needed. A simple and unique system of preforming fiber glass mat was set up and is operating successfully. The cost and factory space for the conventional system requiring large blowers, ovens, and numerous preform screens has been avoided. The cost of glass in mat form and the waste in certain types of patterns is offset by the reduction in scrap and high quality of the molded product.

Mold Rooms.

Because dirt must not be blown on the mold surface during the mold-coating process and because a small amount of styrene vapor is released in the air upon spraying the mold, it was necessary that mold rooms be set up with proper air exhaust and filtered make-up air inlet. Ports of entry for preforms and resin have been provided along with exit doors for removing molded parts.

Operation.

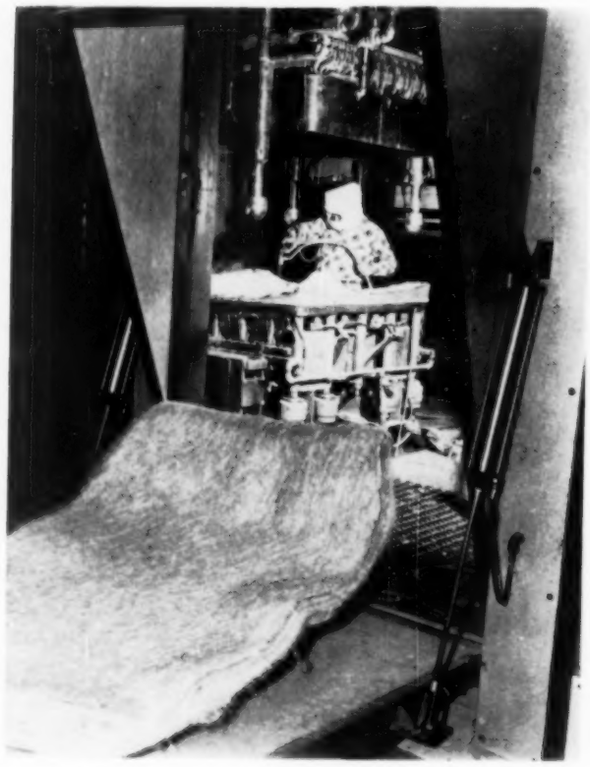
High quality bath tubs are being produced on three presses and a popular car top is also being produced with a mold coated surface to facilitate finishing and painting.

Patent Protection.

Five patent applications have been filed covering the features described above and five more applications are in process of preparation.

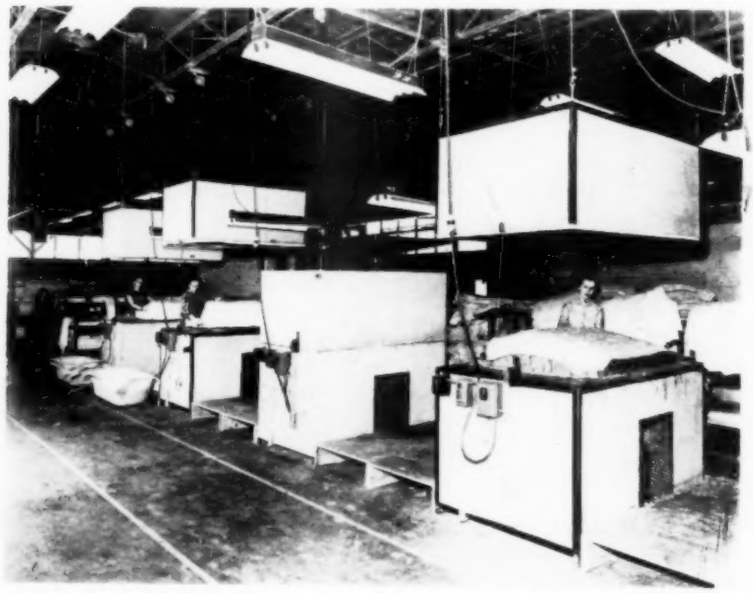
Car Top Mold Through Preform Door

Mold operator is shown spraying polyester mold coat on the stainless steel surface. A similar application is made in bath tub production. Preforms are loaded on the platform door, which, when closed, make these handy for insertion in the mold.



Preform Machines

Low cost of manufacturing equipment, minimum floor space, and accuracy of glass distribution are obtained by preforming mat. Several layers of mat are used with a polyester binder. Seams in the preforms are overlapped for strength and no seam is located directly over one in the adjacent layer.



Irradiation of PLASTICS

By David S. Ballantine
Brookhaven National Laboratory

During the past several years an increasing interest in the effect of radiation on the properties of organic plastic materials has been developing. A number of papers and review articles have been written describing in detail the physical and mechanical property changes which occur when polymeric materials are subjected to intense radiation dosages. These are of great value if one is interested in tensile strength, Rockwell hardness, elongation changes and other physical properties of a particular plastic. In a number of cases, however, conflicts in the data derived from experiments conducted at different laboratories have appeared, so that areas of confusion exist. There has been little attempt to delineate the underlying reactions which occur, and their relationship to the changes observed. It is the object of this review paper to depict the chemical reaction mechanisms involved as a result of irradiations, to show how these reactions can be modified, and to summarize the significant results obtained to date.

THE TERM "RADIATION" as used in this paper includes electromagnetic radiations of the X-ray or gamma ray variety, high energy electrons emanating from radioactive beta decay or from machine accelerators, and, to a lesser degree, neutrons. Neutrons have been utilized in work done in a nuclear reactor core, and here the effects are due to combined neutron, gamma, and beta interaction. Because of the heterogeneous character of the radiation in these instances, interpretation of results is more difficult. It is extremely doubtful that neutron irradiation of plastics will ever be of significant interest because of the factor of induced radioactivity. As a result of neutron interaction, materials can be rendered radioactive, whereas gamma or beta radiation produces no radioactivity.

In order to understand the various changes which have been observed in irradiated plastics, it is necessary to explain the primary processes which take place when radiation interacts with matter. When gamma or beta radiation is absorbed there results in roughly equal amounts both ionization and excitation of the molecules irradiated. Consequent to this primary production of ions and excited molecules, other active species, called "free radicals," can be formed. These processes are graphically summarized in the following equations:

(M ★ signifies a positively charged ion)

$M + \gamma \rightarrow M^{\star} + e$	(ionization)	(1)
$M + \gamma \rightarrow M^{*}$	(direct excitation)	(2)
$M^{\star} + e \rightarrow M^{*}$	(excitation via charge neutralization)	(3)
$M^{*} \rightarrow R_1 + R_2$	(radical formation)	(4)
$M^{\star} \rightarrow R_1 + H^{\star}$	(radical-ion formation)	(5)

As a result of equation (1) an ion pair is formed and this ion pair may recombine to form an excited molecule (M^*) according to equation (3). The positive ion formed in (1) may alternately decompose to a smaller ion (in this case $H^{\star}$) and a free radical (R_1) (Reaction 5). The excited molecule (M^*) formed by equation (3) and also directly by equation (2) has the ability to split into free radicals ($R_1 + R_2$) by equation (4). Thus one may anticipate formation of ions, free radicals, and excited molecules.

While these are all possibilities, experiments to date can best be interpreted in terms of free radical intermediates from which one may deduce that the lifetimes of the primary ions and excited molecules are extremely short. It is the chemical changes which ensue upon formation of these free radicals which determine the physical and mechanical changes in the original plastic.

It is a characteristic of the original radiation absorption process that the ionization and excitation may occur at any point in a complex molecule and is a function only of the electron density. This is unlike ultraviolet activation in which a particular bond can be activated by selecting the appropriate wave length at which that bond absorbs. It is further known that the activation imparted as a result of radiation absorption is free to distribute itself throughout the entire molecule and need not be localized at the primary ionization or excitation point. Thus, (1) any bond is capable of being activated to the point where rupture can occur, and (2) a variety of radical species is capable of formation. It can readily be seen, then, that the nature of the effect produced will be, to a large degree, a function of the chemical composition of the material under investigation.

Suppose one considers at this point the case of a linear polymer with a repeating unit $[-CXY-CH_2-]_n$ where n is a large number, 10^2 to 10^3. The polymer material will consist of a large number of these long chains held together by van der Waals' or other secondary intermolecular forces. When this material is subjected to radiation one can consider that the "n" unit as a whole becomes activated. Actually, this activation may be transmitted to an "n" unit many carbon atoms removed. In the simplest

Work partially done under contract with the U.S. Atomic Energy Commission.

case, polyethylene, the X and Y atoms are also hydrogens so only carbon-carbon, C-C, and carbon-hydrogen, C-H, bonds need be considered. In Figure 1 is shown an idealized polyethylene molecule in which R_1 and R_2 are long (—CH_2—) chain extensions. Considering only this molecule let us assume the activation occurs in the unit containing C_4-C_5. Free radical fragments can be formed by scission of any of the C-H bonds in this unit or by scission of the C_4-C_5 bond.

If a C-H bond is scissioned, a hydrogen radical and a polyethylene radical are formed. There is a possibility that

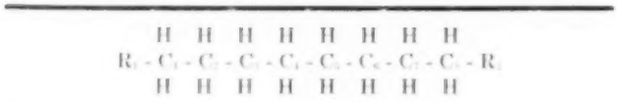


Figure 1. Idealized Polyethylene

these two radicals can recombine to yield the original molecule before any change occurs. This recombination reaction will be favored by any factor, such as low temperature, which prevents rapid diffusion away of the H radical formed. Any H radical which diffuses away can (1) combine with H radicals from other molecules to form a molecule of hydrogen gas; (2) abstract an H radical from another carbon in the same chain to produce a molecule of hydrogen gas and leave a polyethylene fragment with two radical sites; or (3) abstract a hydrogen from a neighboring chain yielding again hydrogen gas and forming a second polyethylene radical. In the case of actual non-idealized polyethylene the H radical can seek out unsaturated carbon-carbon double bond, C=C, side groups and reduce this unsaturation. If by process (2) above a polyethylene fragment with two radical sites is formed, these sites can migrate together and produce a C—C bond in the main chain. It will be noted that this radical site migration assumes also simultaneous hydrogen atom migration.

If two of the polyethylene radicals formed by direct C-H bond scission or by hydrogen abstraction combine intermolecularly, it is obvious that a link between two chains will result. These reactions which may follow the scission of a C-H bond into radical fragments are shown graphically in Figure 2. As a result of these reactions it is possible to observe (1) hydrogen gas evolution, (2) reduction of side chain unsaturation, (3) increase in main chain unsaturation, and (4) crosslinking. Of these, crosslinking will cause the predominant change in the physical and mechanical properties of the original polymer, because these crosslinkings, like vulcanization, cause a gel structure to be built up.

Now let us consider the reactions which may proceed following the scission of the C_4-C_5 bond in the main chain. Such a scission would lead to formation of two polyethylene radical fragments. Again there is the possibility that these two fragments can recombine before further reaction can occur. In this instance the recombination rate would be higher than in the case of a hydrogen radical and a polyethylene radical, because the two polyethylene fragments, being much larger than a hydrogen radical, would diffuse apart at a considerably lower rate.

The radical site can also shift to other carbons on the chain. If recombination occurs following this process the resulting polyethylene molecule will be branched.

However, if in the reaction just cited the radical activity shifts from the end of both fragments before recombination, the result will be crosslinking.

The polyethylene radicals formed by chain scission have the capability of undergoing a rapid chain degradation or depolymerization process. This involves rapid

Figure 2

Processes Which May Result from C-H Bond Scission

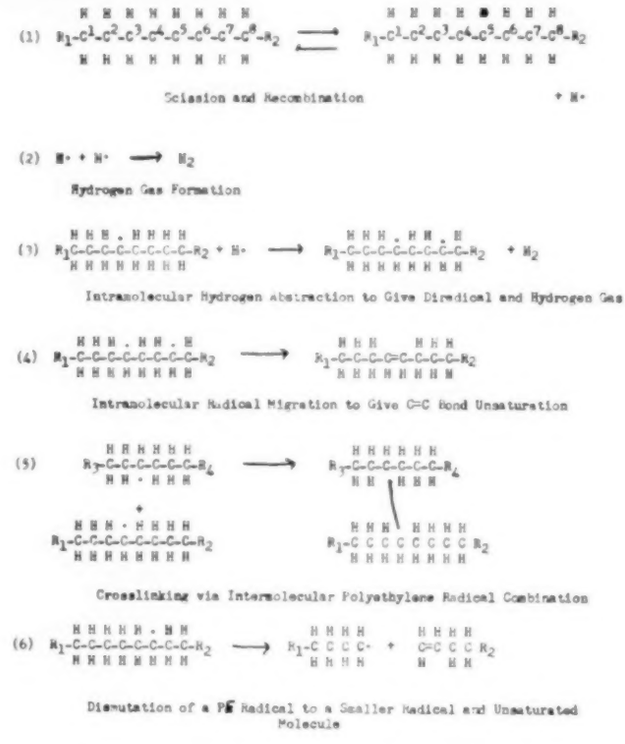
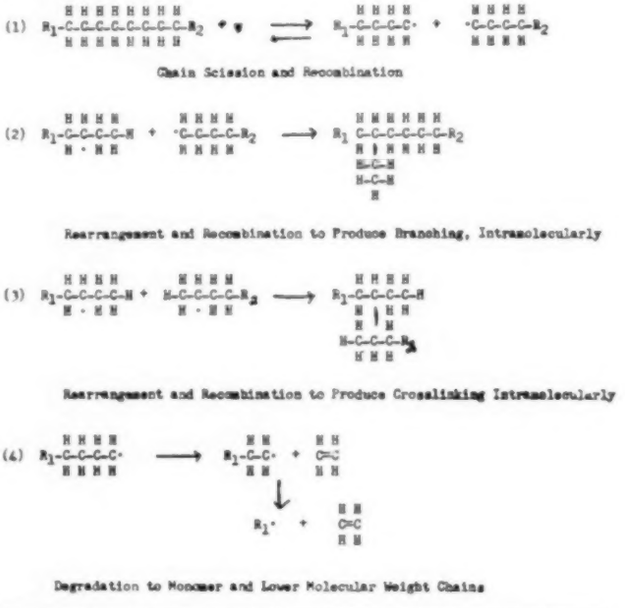

(1)
Scission and Recombination
+ H·
(2) H· + H· ⟶ H_2
Hydrogen Gas Formation
(3)
+ H_2
Intramolecular Hydrogen Abstraction to Give Diradical and Hydrogen Gas
(4)
Intramolecular Radical Migration to Give C=C Bond Unsaturation
(5)
Crosslinking via Intermolecular Polyethylene Radical Combination
(6)
Disputation of a PE Radical to a Smaller Radical and Unsaturated Molecule

Figure 3

Processes Which May Result from C-C Bond Scission



elimination of monomer units unless a chain termination step occurs involving the degrading polymer radical and some other radical fragment. This depolymerization reaction could have followed the C-H bond rupture in the

following manner. The polyethylene radical resulting from a C-H rupture can undergo a dismutation process which yields a polyethylene fragment with the radical site on the terminal carbon and some molecular entity. The polyethylene terminal radical formed by the dismutation process is identical to one formed by a C-C bond rupture. It should be noted that the dismutation process takes place much less readily than the depolymerization process so most degradation will derive from direct C-C bond scission. It should also be noted that this depolymerization is a rapid chain reaction process.

Scission of C-C Bond

Therefore scission of the C-C bond can lead to (1) hydrocarbon gas formation, due to the dismutation and degradation processes or direct chain scission, if the C-C bonds near the chain ends are affected; (2) branching; (3) crosslinking; (4) degradation. These various reactions involving C-C bond rupture are shown graphically in Figure 3. In this instance the major physical and mechanical property changes would derive from the crosslinking and degradation reactions. The physical mechanical properties which are generally changed by crosslinking are tensile strength, breaking, elongation, and hardness. Crosslinking increases Young's modulus, tensile strength, and Rockwell hardness, but decreases elongation. Polymers which undergo cleavage show marked changes in strength and softening characteristics. (An excellent and detailed account of property changes in polymers crosslinked and degraded by radiation has been made by Sisman and Bopp).

Since the absorption of the radiation is a random process, one may expect that all of the above reactions will take place. The relative extent to which each will take place will determine the ultimate change in physical properties.

Factors such as bond strength and the number of each bond type will have an influence. In polyethylene, for example, there are roughly twice as many C-H bonds as there are C-C bonds. However, the C-C bond has a bond energy of 58.6 K cal/mol as opposed to 87.3 K cal/mol for the C-H bond. The former fact would favor C-H rupture and the latter C-C bond scission. As mentioned previously, because of the small size of the H radical, recombination after C-H bond scission would be considerably less than recombination following a C-C bond rupture.

One must also consider the stability of the various radical entities which are possible, since the more reactive species would contribute considerably more to the total change involved. When one considers that each of the reactions mentioned may have a different reaction rate and temperature coefficient, it is not surprising that very little is known of the basic reactions involved when polymers are irradiated. The best that one can do is to deduce from the chemical and physical changes observed experimentally which reactions are playing the leading roles.

Irradiated Polyethylene

Thus, because irradiated polyethylene loses its elongation properties, improves in heat deformation characteristics, and becomes hard and ultimately brittle, one assumes that crosslinking is the predominant reaction. (1,2,3,4) However, physical chemical studies have shown that while gel structures are formed, a soluble sol portion is also produced, indicating that a chain scission process is also operating. (5)

Thus far consideration has been centered on the simplest linear plastic, polyethylene. Now let us see how the reactions outlined above can vary as the X and Y groups in the monomer unit [—CXY—CH$_2$—] are varied. More succinctly, what is the effect of chemical structure on the various reactions?

The work of Burton (6) at the University of Notre Dame and observations by various researchers on radiation stability of plastics lead to the conclusion that substitution of an aromatic nucleus for X or Y in the [—CXY—CH$_2$—] unit increases the resistance to change. Styrene is an example of plastic of this type. The explanation offered for this stabilization is that the activation imparted to the molecule as a whole becomes channeled into the complex benzene nucleus where it becomes dissipated as resonance energy without rupture of C-C or C-H bonds. This resonance process visualizes rapid movement of the energy among all bonds with no localization. However, one might also expect, because of the larger size of the benzene group, that steric factors would tend to reduce any tendency to crosslink.

Some attempt at quantitative evaluation of the extent of this protective influence was made by Alexander and Charlesby (7) using napthalene substituted dodecanes. Dodecane being a twelve carbon saturated hydrocarbon, is a low molecular weight analog of polyethylene. Charlesby determined the dosage required to render dodecane and various napthalene substituted dodecanes insoluble, due to cross linking. These data are given in Table I where radiation is given in pile units.*

TABLE I

Pile Units Required to Render Dodecane Infusible

Substituent	1-Dodecane	4-Dodecane	6-Dodecane
1 Napthyl	43	—	—
2 Napthyl	43	62	66
2 Decalyl	—	—	37

Dodecane alone required 27 pile units.

**A pile unit was defined as neutron flux of 10^{17} slow neutrons/cm^2 plus associated γ radiation. It is equivalent in these experiments to a gamma dose of 4.5×10^7 roentgen from Cobalt 60.*

It can be seen that the aromatic naphthyl group more than doubled the radiation dosage required to produce infusibility and that the greatest effect was felt when the substitution was on a carbon in the middle of the chain. The decalyl substituent, which is about the same size as the naphthyl, except that the aromatic character has been destroyed by reduction, caused an increase from 27 to 37 pile units to produce the same effect. From this one may deduce that part of the effect is due to steric factors, but the major factor is due to the aromatic nature of the naphthyl group.

Another class of commercial plastics in which an X or Y in the unit is replaced by chlorine is the polyvinylchlorides and polyvinylidene chlorides. These materials are characterized by evolution of hydrogen chloride (HCl) gas. (2,8) This can be due to direct H and Cl radical combination or by abstraction of a chlorine atom from the polymer chain by a hydrogen radical. This latter reaction involving Cl removal is similar to the transfer reaction widely observed in polymerization reactions involving halogenated solvents or polymers. This reaction then proceeds at an even greater rate after removal of one HCl molecule from a chain, because the elimination leaves a residue of the structure [—CH=CH—CHCl—CH$_2$—] in which the chlorine is now a more reactive allylic chlorine. Such chain-like loss of HCl produces a high percentage of C=C bonds which accounts for the darkening also observed. The HCl evolution naturally results in a rapid decrease in

the dielectric strength. At first the plastic material softens and later crosslinking results in hardening. Polyvinyl acetate behaves somewhat similarly. In this case the acetate side group is susceptible to decomposition and carbon monoxide and carbon dioxide are formed.

Fluorine Polymers

Teflon and Kel-F are instances in which all the hydrogens in the linear polymers have been substituted. After relatively short irradiation dosages these materials embrittle and crumble apart. (2) Charlesby (9) failed to find any trace of fluorine gas when Teflon was irradiated, but only low molecular weight fluorocarbons. The rapid chain scission was therefore attributed to the difference in bond energy of the C-C link, 58.6 k cal/mol, and the C-F bond, 107.0 k cal/mol.

The general group [—CH—CR—] where R is any group other than hydrogen includes such polymers as polyisobutylene, polymethylmethacrylate, and polyalphamethylstyrene. Lawton (10) and coworkers have come to the conclusion that all polymers of this general structure undergo degradation in preference to crosslinking. Butyl rubber has been observed to degrade to a viscous liquid, while polymethylmethacrylate and polyalphamethylstyrene become embrittled (2). Both these effects are what are anticipated as a result of main chain scission. Lawton (10) has attempted to explain the instability of this group in terms of relative stabilities of the radicals which are formed. If the polymer irradiated is polymethylmethacrylate, one can consider that a radical is formed by scission of one of the C-H bonds in the alpha methyl group. Such a process would leave a radical which is not capable of stabilization by resonance with the ester group. Hence it will tend to decompose to a more stable radical and break a main chain in the process. On the other hand, if one considers polymethylacrylate which contains a hydrogen in place of the alpha methyl group, a radical can be formed which is capable of stabilization by resonance with the ester group. This stable radical can react with a similar radical in a neighboring chain producing a crosslink.

Wall (11) has pointed out that those polymers which degrade have lower heats of polymerization than polymers which crosslink (See Table II). This is an indication of a steric factor which hinders monomers containing 2 R groups in the alpha position from adding to a growing chain. Similarly, upon scission of a polymer chain linkage involving the carbon containing the two R groups, the rate of recombination would be decreased because of steric repulsion. Chain cleavage and depolymerization would then be facilitated.

TABLE II
Correlation of Heats of Polymerization with Irradiation Effects

Direction of Irradiation-Effect	Polymer	Heat of Polymerization (k cal/mol monomer)	Monomer Yield Wt. Percent
Crosslink	Ethylene	22	0.025
Crosslink	Propylene	16.5	2
Crosslink	Methylacrylate	19.1	2
Crosslink	Acrylic Acid	18.5	—
Crosslink	Styrene	17	40
Degrade	Methacrylic Acid	15.8	—
Degrade	Isobutylene	13	20
Degrade	Methyl Methacrylate	13	100
Degrade	α-Methylstyrene	9	100

As a general rule it may be said that if a vinyl polymer contains at least one hydrogen on the alpha carbon it will crosslink in preference to degrading, but if no hydrogens are present the trend will be toward degradation.

Other Types of Polymers

All the polymers considered to this point are linear vinyl addition polymers which are formed by chain propagating free radical processes. Because of this they are also capable of rapid chain depolymerization and upon irradiation this chain depolymerization can assume major importance. One can also consider the case of linear polymers such as the polyamides, polyesters, polyethers, polyxanthates, and silicones which are formed by condensation type processes. Because they are not capable of chain depolymerization by a radical process, they should exhibit a greater tendency to crosslink.

However, now one is considering a main chain which contains no longer a pure C-C structure but has C-O-C linkages as in the polyethers, C-N linkages as in the polyamides, or C-S linkages as in the polyxanthates.

Polyallyldiglycol carbonate which has a main chain oxygen-to-carbon ratio of 0.5 undergoes softening, an indication of degradation, while Selectron 5038, having an oxygen-carbon ratio 0.25, undergoes hardening. (12,13) This suggests a relationship between chain scission tendency and the percentage of oxygen in the main chain of a polyester.

Nylon is quite similar structurally to polyethylene except for an amide group at every sixth carbon in the main chain. It has been observed to undergo crosslinking, and in general has a radiation stability equivalent to that of polyethylene. (2,13).

The Silicone Resins

The silicones with the general formula

$$[-Si(CH_3)_2-O-]$$

have no carbons in the main chain, but are somewhat analogous to polyisobutylene which also possesses two lateral methyl groups. The behavior of the two polymers is entirely different. Polyisobutylene undergoes chain scission and chain degradation, while the silicones crosslink. Dimethylsilicone oils can be converted from oils to rubbers to a brittle-like substance after 2 percent crosslinking. Charlesby (14) rendered silicone oil infusible after about 56 million roentgen and calculated that the energy expended per crosslink was 32 ev, the value found for polyethylene. He also reasoned from the ratio of hydrogen and methane gas evolved that the crosslinking is a combination of Si-C-Si and Si-C-C-Si links.

The difference in behavior between the silicones and polyisobutylene may be attributed to three factors which would decrease the tendency of the silicones to undergo chain scission and degradation. First, the Si-O main chain bond is stronger, 89.3 K cal/mol, than the C-C bond, 58.6 K cal/mol. Second, the oxygen in the silicone chain has no atoms attached which might sterically hinder a recombination reaction after a main chain scission, and third, the silicones are not chain reaction addition type polymers, but condensation type polymers.

The polyesters have been observed by Sisman (2,13) to become embrittled, indicating a significant chain rupture process. This observation is concurred in by Little (15) who irradiated polyethylene terephthalate. This is somewhat surprising when one considers the polyethylene segments in the linear polyesters. At this time it can only be suggested that the chain rupture is caused by radiation decomposition at the ester linkage in the chain with

perhaps some effect from steric repulsion between chains due to the phenyl groups.

While the initial attack of radiation on a molecule is more or less random, the activation has been observed to center in certain groups. Breger (16) on irradiation of long chain fatty acids observed a preponderance of carbon dioxide in the products due to carboxyl group decomposition. In the polyesters this activation may direct itself preferentially to the ester group.

Cellulose materials exhibit a high instability when exposed to radiation and the effect is one of chain scission (2). The cellulose chain can actually be degraded to the point where the original insoluble cellulose has been converted to a soluble sugar-like material (17). This great sensitivity is reflected in the cellulose-based plastics by a rapid embrittlement and loss of tensile strength upon irradiation. There is some justification for believing that this sensitivity is due to the large number of hydroxyl groups present in cellulose. The hydroxyl group is known to be sensitive to rupture with the formation of OH radicals. Thus, in radiation-initiated styrene polymerizations, rates were found to be much higher in water emulsions (8) and in alcohol solutions (19), where initiation probably proceeds from the OH radicals formed.

Non-Linear Polymers

Up to this point consideration has been given only to polymers which are essentially linear. In these cases the major changes in the physical and mechanical properties derive either from a crosslinking reaction or from a chain scission reaction. However, if we now consider resins such as phenolformaldehyde condensation products, there is already present a highly crosslinked polymer. Then any change due to radiation-initiated crosslinking would be insignificant. Therefore, the reactions materially affecting the thermosetting polymers would be chain scission, which would break down molecular structure, and side reactions, such as gas evolution or production of unsaturation. The stabilization of aromatic groups, and the sensitization imparted by such groups as chlorine and hydroxyl, would still be expected to be in effect.

The effects discussed have not included complications which may occur when the irradiations are performed in the presence of oxygen or other impurities.

The radicals resulting from the radiation interaction can react very rapidly with oxygen to produce peroxy radicals or peroxide and hydroperoxide linkages. These peroxy radicals have greater reactivity in many cases than have the hydrocarbon radicals, and as such can attack C-H and C-C bonds more readily.

A very important reaction which one must consider is that of oxidative degradation. It is well known that if polymers are heated in the presence of oxygen, their rate of degradation to monomer can be accelerated. This process involves the presence of intermediate peroxide free radicals. It has actually been observed (20) that when styrene is irradiated in vacuum the main reaction involves crosslinking, while the same irradiation performed in air results in chain degradation.

When polyethylene is irradiated in the presence of oxygen there is an increase in the number of hydroxyl groups, OH, and carbonyl groups, C=O, due to oxidation reactions. (1,3,4,21) Chapiro found that polyethylene irradiated at low intensities in an air atmosphere contained peroxide and hydroperoxide linkages. While stable under normal conditions, heating to about 150°C caused rupture of these oxygen-containing links. The presence of such active groups could markedly alter the aging qualities of an irradiated plastic.

Great care must be taken in comparing results from different sources, since the presence of air can not only alter the extent of an effect, and the rate at which it occurs, but in some cases can alter the very nature of the main effect.

The presence of other impurities can be equally important. Sisman and Bopp (2,12) cite the effect of fillers on the radiation stability of phenolformaldehyde resins. While mineral-filled phenolformaldehyde resins ranked among the highest in stability, the same resins, when filled with cellulose materials, were much less stable. This represents a case in which the stability of the finished material was a function not of the plastic itself, but of the filler material.

There is evidence of radiation protection which is intermolecular in nature. Alexander and Charlesby (7) measured the radiation required to produce one main chain scission in polymethymethacrylate. Films of polymethylmethacrylate containing 10 percent of aniline, allythioures, and dimetatolylthiourea were then cast and the energy required for a main chain scission was measured. The energy required was two to three times that for pure polymethylmethacrylate. When one considers that surface contact in these films was small, it becomes apparent that the energy imparted by radiation was transmitted over large distances.

Much work has been devoted to improving the radiation stabilities of organic materials in general, by addition of antioxidants and free radical inhibitors. The general philosophy is to attempt to neutralize any radicals formed from radiation interaction before crosslinking or degradation or other reactions can occur. While some success has been obtained, the protective effect is only temporary and disappears as the protective agent is exhausted.

Within the foregoing pages the author has attempted to show that the interaction of radiations with polymers results in a complex set of radical entities and a spectrum of possible reactions. The course of the various reactions will be determined by the activity of the various radicals, the number and strength of the bonds in the molecules, the chemical composition of the polymer itself, steric factors, the presence of oxygen, the use of fillers, and the addition of protective agents. Where possible, suggestions have been made as to how these parameters affect the direction or extent of the two principal reactions—crosslinking and chain rupture. Unfortunately, most of the existing data have not been obtained for the purpose of establishing basic principles. With few exceptions the approach has been toward measuring gross physical changes due to radiation.

It is felt that there is a need for a wide range of basic kinetic and mechanistic studies in this field. Much can be learned from the use of radioisotopes in the study of the behavior of competent parts of polymer molecules, and from the application of various tools of spectroscopy, by which changes in chemical composition can be quantitatively followed in a continuous fashion. Only when these and the other modern tools of science are applied, can research in radiation effects proceed on a firm basis.

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3. Ballantine, D., Dienes, G. J., Manowitz, B., Ander, P., and Mesrobian, R. B., J. Poly. Sci. XIII, No. 70, 410 (1954).

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book reviews

POLYMER PROCESSES, Volume X of High Polymers, edited by C. E. Schildknecht. Published 1956 by Interscience Publishers, Inc., 250 Fifth Ave., New York. 934 pages. Price $19.50.

Polymer Processes is descriptively sub-titled "Chemical Technology of Plastics, Resins, Rubbers, Adhesives and Fibers." It is a noteworthy addition to the High Polymer Series, and in many ways is the best. The purpose of the book is expressed in the preface: "—the chemical aspects of polymer **technology**, especially the newer processes employed for preparation, formulation and shaping of plastics, rubbers, fibers and adhesives, have remained comparatively unavailable. This book—is devoted to basic processes used in the polymer field, particularly with a view to bridging the gap between theory and practice."

Polymer Processes is as complete and up-to-date as could be hoped for within the covers of a single volume. It will probably be of greatest interest to chemists and engineers involved in either production or processing. The plastics molder will find the book easy to read and valuable as the background for understanding why plastics behave as they do and what can reasonably be expected of each type; the actual discussions of molding and shaping he will find elementary, but a fair summary of standard practices.

All in all Polymer Processes is a good job, very well done. References to patents and original literature make it possible to follow any point of interest in detail.

Numerous drawings, charts and graphs illustrate the points discussed.

Chapters and authors are listed to show scope of coverage.

1. **Introduction to Free Radical Polymerization.**
   J. H. Baxendale
2. **Polymerizations in Bulk.**
   C. E. Schildknecht
3. **Polymerizations in Suspension.**
   E. Trommsdorff and C. E. Schildknecht
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    G. S. Garvin
17. **Polymer Reinforcement.**
    H. L. Gerhart and E. W. Moffett
18. **Spinning and Drawing Fibers.**
    J. L. Riley

Appendix.
Index.

Jesse H. Day

Der Spritzguss Thermoplastischer Massen

(Injection Molding of Thermoplastic Materials)
by Dr. M. E. Laeis.
Published 1956 by Carl Hanser Verlag, Munich.
301 Pages. 180 Illustrations.
Price: DM 29,00 (ca. $6.90).

Not since "Injection Molding of Plastics" by Islyn Thomas (Reinhold, 1947) has there been a similar book covering all aspects of the Injection Molding Industry. This is the first full length German language book on the subject, giving up-to-date information on the development of injection molding in Germany and 21 other countries. The author (see SPE Journal, February, 1955, page 29) has been active in the construction of injection presses for over a quarter of a century, most of this time as president of Eckert & Ziegler GmbH, a firm which is second only to Reed-Prentice Corp. in total number of injection presses delivered on a world-wide basis.

By way of introduction, this book defines and explains the injection molding process, as well as the general construction features of modern injection presses. The historical development of the press is carefully traced across a century, from the Sturgiss die-casting machine of 1849 to the fully automatic injection machines of the 1950s.

The outstanding chapter of the book deals with standard injection presses manufactured since 1945. The list includes 66 manufacturers and the specifications of 294 models from a dozen countries. Numerous photographs of the presses supplement the technical data. While the section on American machines is somewhat incomplete, this is nevertheless a most remarkable effort to collect information of injection presses made all around the world, and at the same time a strong appeal to the manufacturers for the need of standardization.

The chapter on mold construction covers all standard mold types, methods of molding undercuts and threads, cam actions, and gate shearing devices. Under the heading of "Materials," the various thermoplastics are discussed, together with charts of trade names and manufacturers' addresses.

The technology of injection molding is completely covered, from proper material storage and preheating, through the molding process in general and as applied to the various materials, up to the finishing and decorating operations. For the estimator, there is the reproduction of the form currently used by a leading German molder in quoting tool costs and piece prices. For the designer, some general rules to be observed in product design are explained and well illustrated. For the consumer, there is

(Please turn to page 50)

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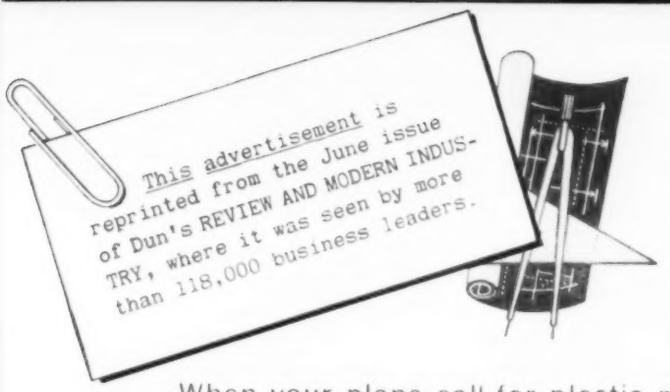
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Rene P. Magnenat, Waterbury Companies, Waterbury, Conn.
Nearly 35 years ago Mr. Magnenat left his native Switzerland to seek greater opportunity for his engineering talents. In 1922 he joined Waterbury Button Company, now a subsidiary of Waterbury Companies. Mr. Magnenat soon busied himself with the molding of phenolic plastics, and today his fascination with this material continues. In ten years, Mr. Magnenat believes more items will be made of plastic than anyone dares dream of today. Because of these new potential uses for plastics, he, like other outstanding craftsmen, is paying close attention to new materials.

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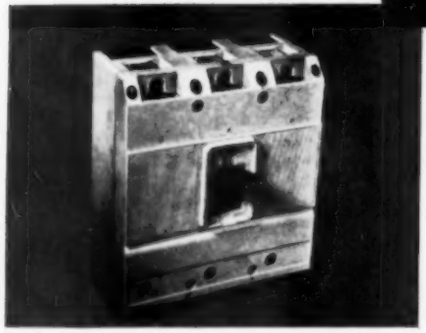

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LIKE AN OUTSIZE TRUNK ON WHEELS, this reinforced plastic trailer is rented day after day, in all kinds of weather, for less-than-van-load moving. Reinforced LAMINAC® polyester resin makes the trailer light, strong, stable, shock- and corrosion-resistant, easy to maintain. Letters are molded right into the trailer body.

TOPS FOR ECONOMY—school desks surfaced with CYMEL 405 melamine resins laminates. Surface of this desk, made by American Desk Manufacturing Company, is good-looking, smooth and sanitary, easy to clean . . . unharmed by ink, crayon, glue or paste. Minimum maintenance and replacement costs make these desks real money savers!

The material advantages offered by Cyanamid plastics and resins may shape *your* next business opportunity. Call on us for advice and cooperation on melamine, urea and methylstyrene molding compounds . . . polyester resins . . . laminating resins . . . resin adhesives . . . resins for surface coatings.

CYANAMID

AMERICAN CYANAMID COMPANY
PLASTICS AND RESINS DIVISION
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Action— By Your National Organization

"The objects of the Society shall be to promote in all lawful ways the Arts, Sciences, and Engineering Practices and Standards connected with the utilization of plastics."

June 7, 1956

Dear Fellow Members:

As you read in your June issue of the Journal, I, Jimmy Davidson, have been appointed your Executive Secretary. Now that all sounds real simple, doesn't it? Well, it WILL be with such a fine national organization, with the finest local sections of any technical society, and the sound core of individual members, which constitute this, the Society of Plastics Engineers.

It is with humility that I accept this office, and gratitude for the confidence your councilmen have placed in me. In return for this confidence I shall be constantly alert toward our goal of making our society the first on the roster of National Technical Societies. We can do this by education; education of the consumer through improved public relations; education of the manufacturer by showing him his responsibility toward improved products and the necessity for greater cooperation with educational institutions for the consistent upgrading of his future engineers; education of our members and future members by getting our technical information into the hands of everyone who needs it—particularly the new engineers and associates coming into our field.

There is no question that all industry is moving ahead today at a phenomenal speed and our plastics industry is certainly leading this parade. As we are the only society devoted exclusively to promoting the "arts and sciences, and engineering practices and standards connected with the utilization of plastics," it becomes our responsibility to work with industry and education to interest more young men in our field and then make possible their education there. The work of our society along these lines is outstanding. By working with the associated college movements and various foundations to make available awards, scholarships, and fellowships, and, of course, eventually by our own research activity, we will be able to develop engineers for membership in some proportion to this accelerated demand. In the March 1955 Journal our Education Committee covers this subject of plans for the future supply. By working at both the Sectional and National level in this direction, we can supply the answer to Mr. Lloyd A. Chacey's article "Plastic Engineers — When?", in the October 1955 Journal. We should start now by creating a Student Membership status, then work through our sections with the local colleges and high schools to get activity.

Another important activity is our continued effort for closer relationship with our sister societies. This effort is the particular responsibility of our Cooperative Technical Progress Committee (February '56 Journal). This should be expanded, as we go ahead to increase our stature, gain prestige, and extend public relations, to such organizations as American Society for Engineering Education, Engineers Joint Council, U. S. Chamber of Commerce, S. P. I., and others.

Our Journal is one of our very effective means of reaching out to tell our story at all levels, for our circulation coverage is good and is reaching for ever expanding horizons. The Journal's "New Look" — March 1956, tells the story of the excellent growth of our Journal. We must have constant effort toward greater circulation, for it is by constantly increasing the length and breadth of our coverage that we can call for and receive increased advertising, and more and greater technical content, and through this medium we can excel as the "First Book" on plastics in the field.

Through the good work of our Professional Activities Groups, by the increased publishing of books and technical papers, we are able to lay down guide lines for the advancement of you — our membership; for it is the job of our society to encourage the professional development of our members and promote proper recognition of the profession.

My sincere desire is the constant improvement of the services of the National Organization to you — the membership. I want to thank you for your splendid cooperation as we move ahead together.

With kindest regards,

Jas. R. Davidson
EXECUTIVE SECRETARY

James R. Davidson

Industrial Literature

Injection Machines

A new six page bulletin describes the operating features and specifications of the Watson-Stillman PE-64 Preplasticizing Type, Plastics Injection Molding Machine.

The bulletin also describes the latest design features such as the improved heating cylinder, new base design, prefill system, preplasticizer unit and accessory equipment. Complete information on machine speeds and die space dimensions is also included.

Copies of Bulletin 624 may be obtained by writing to Watson-Stillman Press Division, Farrel-Birmingham Company, Inc., 109 Aldene Road, Roselle, New Jersey.

Thermocouples

Conax Catalog 1556 is just-off-the-presses.

This new complete Conax catalog of thermocouple assemblies and pressure sealing glands introduces the new Conax Check Wells, Conax Speedwells, Conax Multiple Wire Thermocouple Glands, Conax Pressure Sealing Spring Loaded Thermocouples and Conax Flex-tube assemblies. Write to 7811 Sheridan Drive, Buffalo 21, New York.

Prepackaging

Prepackaging—from the points-of-view of retailers, distributors and manufacturers—is fully explored in the new, completely revised edition of a 32-page booklet—"How to Prepak In Corrugated Boxes"—just published by Hinde & Dauch, Sandusky, Ohio.

Vulcanized Fiber

"Vulcanized Fibre—The Laminated Plastic With A Million Uses" is the title of an 8-page reprint currently being offered by National Vulcanized Fibre Company.

This reprint, from the editorial pages of Plastics Industry, is a refresher course for designers and engineers on the properties and diversified applications of vulcanized fibre—the grandfather of present-day laminated plastics. It is illustrated with 20 photographs — 5 showing forming methods, 15 showing typical products.

Copies of this reprint are available without cost from National Vulcanized Fibre Co., 1056 Beech St., Wilmington 99, Del., or National Fibre Co. of Canada, Ltd., 107 Atlantic Avenue, Toronto, Ontario, Canada.

Plastic Roller Bearings

A 115-page report on the application of plastics to roller and ball bearings has been made available for purchase by Kaydon Engineering Corp., Muskegon, Michigan.

The report covers in detail a special project undertaken for the Research and Development Division of the Detroit Arsenal to determine the best types of plastics for use as rolling elements in heavy-duty turret or cupola bearings on combat vehicles. The project was found necessary since published technical data and mechanical properties have not been adequate for bearing design engineers to utilize plastics in ball and roller assemblies.

Copies of the report are available for $4.75 each by writing to Department PB, Kaydon Engineering Corp., McCracken Street, Muskegon, Michigan.

Farrel-Birmingham

A new 44-page booklet, entitled "This is Farrel-Birmingham," is available on request to Farrel-Birmingham Company, Inc., Ansonia, Conn.

The booklet, with the aid of well-selected illustrations, gives a factual presentation of this company's ability to design and manufacture a wide variety of heavy machinery and machine tools in its four plants at Ansonia and Derby, Conn., and Buffalo and Rochester, New York.

Fluorine Plastics

Two reports of Air Force research and development of fluorine compounds for aircraft applications have been released to industry through the Office of Technical Services, U. S. Department of Commerce.

POLY FBA — A FLUORINATED ACRYLIC ELASTOMER FOR HIGH TEMPERATURE SERVICE IN THE PRESENCE OF AIRCRAFT FUELS AND LUBRICANTS. H. C. Hamlin, Wright Air Development Center. Nov. 1955. 60 pages. $1.50. (Order PB 111946 from OTS, U. S. Department of Commerce, Washington 25.) This report of research contains an analysis of the properties and applications of Poly FBA, a new synthetic elastomer having a unique combination of fuel, oil, and solvent resistance and high temperature stability. Results of many tests suggest application in a variety of types of mechanical goods including seals, diaphragms, hose, coated fabrics, and other items.

Heat Stable Plastics Research Results

Three reports of research in the Air Force's continuing search for polymers with exceptional thermal stability and chemical resistance have just been released to industry through the Office of Technical Services, U. S. Department of Commerce. These reports are described below.

A STUDY AND EVALUATION OF KEL-F ELASTOMER. R. E. Headrick, Wright Air Development Center, U. S. Air Force, Oct. 1955, 41 pages, price $1.25. (Order PB 111984 from OTS, U. S. Department of Commerce, Washington 25.) The bulk of the work reported is a summary of experimental compounding while trying to compound for low compression set and good chemical resistance. Initial compounding of Kel-F elastomer (developed by M. W. Kellogg Co. from work originally sponsored by the Army Quartermaster) revealed the most promising compounds for low compression set and chemical resistance were those cured with benzoyl peroxide. Immersion tests in experimental hydraulic fluids indicate that Kel-F may prove useful for aircraft hydraulic system applications up to 400°F. Tests also indicate that the properly compounded elastomer has exceptional resistance to potential rocket fuels. Of particular importance to the rubber compounder is the discovery that prolonged milling is required during compounding to obtain uniform physical properties. Variation in milling time can change final physical properties as much as 100 percent.

ELASTOMERIC DITHIOPOLYESTERS. F. W. Knobloch, Wright Air Development Center, U. S. Air Force, June 1955, 25 pages, price 75 cents. (Order PB 111949 from OTS, U. S. Department of Commerce, Washington 25.) Elastomers were prepared from an experimental liquid polymer formulation derived from a condensation product of mercaptoacetic acid and triethylene glycol. Two general types of these elastomers are discussed; one was obtained by reaction of the liquid polymer with organic and inorganic peroxides, the other by reaction of terminal mercapto groups with unsaturated aldehydes. Selected specimens of each type of elastomer were successfully compounded and vulcanized using conventional rubber processing equipment. The behaviour of these vulcanizates in fuels and synthetic ester base oils has been studied along with the effects of aging at elevated temperatures.

FLUORINE-CONTAINING POLYETHERS. O. R. Pierce, D. D. Smith, and R. M. Murch, Dow Corning Corporation for Wright Air Development Center, U. S. Air Force, June 1955,

57 pages, price $1.50. (Order PB 111986 from OTS, U. S. Department of Commerce, Washington 25.) The purpose of the research was to synthesize fluorine-containing polymers of the polyether type for evaluation as sealants, rubbers, coatings and adhesives. In particular, the desired properties were high thermal stability, fuel and oil resistance, retention of properties at -65°F., and resistance to fuming nitric acid and ozone. Appreciable quantities of two monomers were prepared by reactions involving the dehydrohalogenation of the corresponding halohydrins.

Alkyd Resins

ALKYD RESINS FOR VINYL FINISHES, Part II — Atmospheric Resistance. S. B. Crecelius, Naval Research Laboratory. Dec. 1955. 17 pages. (Order PB 111824 from OTS, U. S. Department of Commerce, Washington 25, price 50 cents.) A study was undertaken to establish the type of alkyd resin which would give the best performance when used in combination with vinyl resin as topside coatings for Navy ships. Several series of alkyd resins were prepared containing varying percentages of phthalic anhydride, different fatty acids (soya bean, dehydrated castor, linseed, and mixtures of these), and polyhydric alcohols (glycerol, pentaerythritol, ethylene glycol, sorbitol, and mixtures of these). Panels were exposed under several tests, including salt spray. The long-term outdoor weathering test indicated that the maximum corrosion resistance for the glycerol products is at the 28 to 30 percent phthalic anhydride level with little difference shown in regard to fatty acid used. The outdoor test also showed that pentaerythritol products gave the best performance at the 24 percent phthalic anhydride level. The glycerol-sorbitol mixtures performed about the same as the straight glycerol products at 26 percent phthalic anhydride content.

Honeycomb Adhesives

A new 20-page technical bulletin giving engineering data on adhesives for honeycomb structures is now available from Adhesives & Coatings Division, Minnesota Mining & Manufacturing Co., 423 Piquette Ave., Detroit 2, Michigan.

The bulletin gives test procedures and results of testing new resin-type and elastomeric adhesives used for bonding aluminum to kraft paper honeycomb core. Honeycomb sandwich materials and construction details are discussed in the bulletin.

Adhesive application procedures are described in detail. Specification sheets for EC-1177 resin-type 3M adhesive and EC-1357 elastomeric 3M adhesive are also included in the bulletin.

Nine case-histories of how the Stokes Laboratory has enabled manufacturers in different fields to develop new products or manufacturing processes are contained in a 12-page brochure, "At Your Service," recently published by F. J. Stokes Machine Company, Philadelphia, Pa.

Copies of the brochure, Bulletin 640, are available free on request from F. J. Stokes Machine Company, 5500 Tabor Road, Philadelphia 20, Pa.

Men In The News

Duffy at Foster Grant

Francis V. Duffy has been named Director of Sales Research for the Petrochemical Division of Foster Grant Co., Inc., Leominster, Massachusetts.

John W. LaBelle, Sales Director, in announcing the appointment said that Mr. Duffy will work through the H. Muehlstein & Co., representatives contacting management in the molding industry in an effort to correlate the forward thinking of the molders with the forward thinking and future plans of Foster Grant Company.

Mr. Duffy will also act as a liaison between his company and H. Muehlstein's representatives keeping them completely up to date with improvements on present products and new formulations coming along.

Bill Duffy at Stokes

William Duffy has been appointed chief plant engineer of Stokes Molded Products Division of The Electric Storage Battery Company, it is announced by Robert Kent, manufacturing manager.

R. U. Haslanger

Mr. Robert U. Haslanger was appointed President of Escambia Bay Chemical Corporation. He succeeds Mr. Kenneth G. Donald who resigned to devote his full time to his duties as Vice President and Treasurer of National Research Corporation.

Dr. N. C. Robertson, Director of Research, was appointed Vice President.

Bahun and Patel

Charles J. Bahun and Dr. K. U. Patel have joined the Philadelphia, Pa. laboratory staff of the Durite Products Department of The Borden Company's Chemical Division. Mr. Bahun, formerly with Hughes Aircraft Corp. and the Bakelite Company, will serve as group leader in charge of molding material development at Durite. Dr. Patel, who received his Doctorate at Michigan State College and came to Borden's from the Westinghouse Electric Corporation, will serve the development staff as chemical engineer.

W. D. Kleppinger

The appointment of W. D. Kleppinger as executive assistant to the President of Mycalex Corporation of America and associated companies has been announced by Jerome Taishoff, president of the organization.

J. D. Stricker

Appointment of J. D. Stricker as eastern seaboard sales engineer is announced by Paul Roche, sales manager of Nosco Plastic, Inc., Erie, Pennsylvania, custom plastics molder. Mr. Stricker had previously been working as a representative in the molded plastics field for competitive companies in the Ohio area. He has just completed an intensive two-month indoctrination session at the Nosco plant and has recently opened his office at 3318 South Shore Trail, Sparta, New Jersey.

James Thornton

Frank W. Egan and Company, Somerville, N. J., announces that James S. Thornton has joined their organization as Sales Engineer. For the past three years Mr. Thornton has been located in Portland, Oregon, where, with John V. Roslund, he was West Coast representative for the Egan Company. Sales and service for the West Coast will now be handled from the Egan Co.'s new plant and main office, Somerville, N. J.

Gustave Ferri

Mr. A. Nichols, Vice-President in charge of Manufacturing of the Celluplastic Corporation, Newark, New Jersey, today announced the appointment of Gustave Ferri, as Plant Manager of the company's Fitchburg, Massachusetts plant.

Mr. Ferri joined the corporation in 1951. Before this promotion, he was the company's Chief Engineer.

Sidney Pinhasik

Sidney Pinhasik has joined the laboratory staff of the Resinous-Reslac Department of the Borden Company's Chemical Division. He will be located at Resinous-Reslac's Chicago plant, where production and laboratory facilities have recently undergone a sizable expansion. The plant now manufactures a complete line of emulsions, solutions and hot melts for industrial users.

Clare E. Bacon

Clare E. Bacon is the new Chairman of the Reinforced Plastics Division of The Society of the Plastics Industry, Inc., effective June 1, 1956. Mr. Bacon, Manager of Custom Molded Sales of Owens-Corning Fiberglas Corp., New York City, was elected for the next year, succeeding Samuel S. Oleesky, Vice President, Micronics Division, Zenith Plastics Company, Gardena, California.

NEWS of the industry

H-P-M Koehring Merger

Announcement by Koehring Company of plans to acquire through statutory merger, the Hydraulic Press Manufacturing Company of Mount Gilead, Ohio for in excess of $5,000,000 reflects a desire of both companies to jointly capitalize on their recent individual successful efforts at product diversification.

Emphasis was given to this objective when the transaction was disclosed by both companies. It was pointed out that Koehring has acquired three plants in the last five years to backstop its entry into new markets while meeting record demand for traditional products. Hydraulic Press, meanwhile, in the same period, has bolstered its sales potentials by capturing a sizable portion of the plastic injection molding and die casting machine field.

Prodex Extruder

A new plastics extruder, Model E-3, with improved design features that provide better performance is now being produced by the Prodex Corporation, Fords, N. J.

The outstanding feature of this new machine is the fully automatic thermo control with electronic three-position temperature controllers that automatically actuate stainless steel heaters and turbo air coolers, to provide, according to the manufacturer, more precise temperature control. A new heavy duty thrust assembly consists of an extra heavy thrust bearing of the spherical roller type. The drive shaft and thrust bearing are supported by two widely spaced radial bearings.

The extruder also has a herringbone gear transmission and a flexible coupling between the gear transmission and thrust bearing to protect the gear transmission from mechanical shock.

Canadian Resins

Announcement that Canadian Resins and Chemicals Limited will manufacture polyethylene films and lay-flat tubing was made today. Construction of a new plant for this purpose is now underway at Ste. Therese, Que.

When completed, the plant will contain three production lines for the manufacture and treating of polyethylene film. Full production is estimated in six months' time. Initial limited production was made available by the Company in May.

Price Reductions

Price reductions of more than 30 percent on its fluorocarbon rubbers have been announced by The M. W. Kellogg Company. This price reduction, the first since introduction of this material two years ago, is effective June 1, 1956.

KEL-F elastomer, a non-flammable rubber with high resistance to solvents, fuels, lubricants and other chemicals even at high temperatures and weather extremes, was previously priced at an introductory $25 per pound. The new price schedule for the two commercial grades, available in compressed bales of raw gum, starts with a new base price of $15.00 per pound and is on a sliding scale depending on quantity ordered.

The new price per pound schedule for the elastomer is: $16.00 in 1-99 pound lots; $15.50 for 100-1990 pound orders; and $15.00 for orders of 2,000 pounds and over.

Durite Expands

An increase in the Philadelphia, Pa. plant facilities of the Durite Products Department of the Borden Company's Chemical Division has been announced by E. L. Kraft, Durite general manager. The increase will approximately double present warehouse capacity and also enlarge the plant's production area, he said.

The warehouse enlargement has been made necessary by the growing demand for the Company's phenolic resins and molding material, Mr. Kraft explained. The increase in plant area will permit more efficient movement of materials in process and will pave the way for more efficient production, he added.

Logo Additions

M. A. Self, President of LOGO, Inc., Chicago, Illinois announced the completion of a plant expansion program involving the addition of over 7,000 sq. ft. of plant, office and research laboratory space. A new 3,500 sq. ft. building has been erected and equipped at the plant site for use as a paint blending room. Offices and research laboratories formerly located at the plant site have been moved to the Calument Harbor Terminal Building at 130th and Stony Island Avenue, Chicago. Tank farm facilities for bulk handling of solvents, resins, and intermediate products has been increased over 100%.

Fluorocarbon Bonding

"Bondized" CALIFILM (fluorothene, Kel-F) and KELON-F (Kel-F) sheets, specially-treated on one or both sides to allow bonding to a variety of materials or to itself using commercially-available adhesives have been developed by Shamban Engineering Co., Culver City, Calif.

"Bondized" material can be cemented to steel, aluminum, wood, plastics, cardboard, or rubber to provide unique combinations of advantages. Commercial, industrial, and defense applications are numerous in aircraft, automotive, electronic, food processing, baking, candy, carton-making, and many other industries. Bondized film and sheets are especially suited for parts that encounter wear or corrosive conditions such as liners, and coverings for tanks, jigs and fixtures, rollers, bushings, loading hooks, sliding surfaces, pipe, ducts, valve facings and machine parts. For additional information write Sales Dept., Shamban Engineering Co., 11617 West Jefferson Blvd., Culver City, Calif. Telephone number is TExas 0-6877.

Glycerine Award

The Glycerine Producers' Association has announced that the fifth annual Glycerine Research Awards are now open and that nomination blanks are available. This announcement was contained in a new bulletin describing the purpose of the awards, work eligible for consideration, method of nomination and judging, dates by which nominations must be received, and previous winners.

First award is $1000 and an honor plaque, second award $300 and third award $200. These awards are granted for independent research leading to new and improved applications of glycerine or glycerine derivatives to products or processes.

Copies of the bulletin giving complete details on the awards may be obtained from the Glycerine Producers' Association, 295 Madison Avenue, New York 17, N. Y.

Western Electronic Show

The most advanced electronic theories and products of interest to the plastics industry will be presented at the 1956 Western Electronic Show and Convention in Los Angeles, August 21-24. WESCON is sponsored jointly by WCEMA (West Coast Electronic Manufacturers' Association) and IRE (Los Angeles and San Francisco Sections representing the Seventh Region of the Institute of Radio Engineers).

The Show, which will be conducted at the Pan Pacific Auditorium, will feature the exhibits of 650 firms from all over the nation. A major part of them will be related to the advancement of the plastic industry. For more information write to Dept. S.P.E. WESCON (Western Electronic Show and Convention), 344 North La Brea Avenue, Los Angeles 36.

Plaskon - Canada

Establishment of new and expanded sales-engineering services for Plaskon plastics in Canada was announced here today by The Barrett Company, Limited.

According to The Barrett Company, Limited, George H. Martin has been appointed Canadian sales manager for the Montreal and Toronto districts for Plaskon molding compounds, which include urea, melamine, alkyd, and nylon molding compounds. Mr. Martin will be headquartered in Toronto.

Polyurethane

Thiokol Chemical Corporation has announced the development of a new polyurethane prepolymer for resilient water-absorbent foams.

The prepolymer, designated as "Thiokol" ZL-239 can be processed into water-absorbent foams with a combination of properties unobtainable through conventional polyurethane or other resins and materials currently available.

Foamed materials made from ZL-239 are of uniform cell size and smooth texture. They combine resilience and strength, both wet and dry, with water absorption properties equivalent to those of cellulosic materials. For example, tests conducted by Thiokol have disclosed that the water pick-up of ZL-239 foams is about ten times that of conventional polyurethane foams.

Processing of the prepolymer into a foam involves simple equipment only. It can be processed by machine or through a spray gun and can be molded into relatively complex shapes.

Quality Tools

A new line of Reevelec RF heavy-duty, self-contained plastic preheaters has been announced by Reeve Electronics, Inc. Models ranging from 2 KW to 6KW output are available.

Complete information on these preheaters can be obtained by writing Reeve Electronics, Inc., 609 West Lake Street, Chicago 6, Illinois.

F. J. Stokes Co. Changes Name

F. J. Stokes Machine Company, Philadelphia, Pa., will change its name to F. J. Stokes Corporation effective July 1, Francis Dougherty, Stokes' president, announced today, following the company's recent annual meeting at which stockholders approved the change. The new designation was selected as being more in keeping with the broad range of the company's interests and the varied line of production and processing equipment which it has developed during its 60 years of growth.

Plastic Preheaters

A new firm, Quality Tools Corporation, 108 Nassau Road, Roosevelt, Long Island, N. Y., has been set up to manufacture models and molds for use in the vacuum forming of plastic sheet materials. Its president is Sanford S. Zimmerman of Port Washington, N. Y.

Claremont Pigments

Claremont Pigment Dispersion Corp. began full production this month in a new plant at 39 Powerhouse Road, Roslyn Heights, L. I.

Claremont, a leader in the manufacture of dispersed colors for plastics, rapidly outgrew their previous plant at 110 Wallabout St., Brklyn., N. Y. The move to a suburban area follows a consumer and industry pattern of movement to open spaces, more modern facilities and better transportation.

Most important, completely new equipment doubles Claremont's production capacity. A new line of products has been added with the manufacture of color granules for use in Polyethylene plastics. Claremont also increases its manufacture of dispersed colors for Vinyl, Polyester and Epoxy plastics, as well as ink for the plastics industry.

Price Reductions

National Polymer Products, Inc., Reading, Pa., a sales subsidiary of The Polymer Corporation, has announced a price reduction of approximately 40% on its series of NYLASINT nylon powders. The reduction affects all of its specially processed, finely divided nylon powder formulations. These powders are produced in small particle sizes and can be supplied with various inert fillers to provide specific properties.

Phillips Chemical Co.

Phillips Chemical Company, wholly owned subsidiary of Phillips Petroleum Company, on June 1 opened six district offices of its plastics sales division preparatory to full-scale marketing of the company's new family of polyethylenes, trademarked Marlex.

Barrett Expansion

Barrett Division, Allied Chemical & Dye Corporation, has announced plans for substantial expansion of its production of Plaskon polyester and liquid phenolic resins at its Toledo plant. Plans call for more than doubling polyester resin capacity and nearly quadrupling phenolic resin capacity. The new facilities will come into operation by stages with final completion by mid-1957.

Dash is Director

Harriman H. Dash has been appointed as Director of Research for Foam King, Inc. located at 1816 Boston Road, Bronx 60, New York. Mr. Dash will report directly to Joseph J. Hirsh, Vice President in charge of Engineering who is also the inventor of the "Foam King" processes.

Fishing Bugs

Fishing lures — a large assortment of bugs — can be easily molded (in color) using a plastisol, an open face mold, and an ordinary hot plate. The whole shebang is sold as a kit (plastisol, color & mold) for the fisherman by Lois Richards, 2424 Euclid Ave., Cleveland, Ohio.

Teflon Production

Du Pont will double its production of "Teflon" 6 tetrafluoroethylene resin, a fine-powder composition developed for extrusion, it was announced today by William A. Franta, marketing manager for "Teflon."

First produced in commercial quantities last fall, after an extended period of pilot plant operation, interest in the composition has grown to the point where an expansion of manufacturing facilities is necessary, Mr. Franta said. "Teflon" 6 is used for making hose and tapes for electrical insulation, and for insulating wire and cable.

Foreign News

"Industrial Kaleidoscope" is a digest publication which devotes a considerable space to plastics. Most paragraphs are pertinent items reprinted from many sources. Vol. 3 No. 5 is the first printed issue, up from being a mimeographed job. "Interesting" is the word. Published at 147 Grosvenor Rd., Westminster, London.

The International Congress of Chemical Industry meets in Paris, November 18-24. For information write Societe de Chimie Industrielle, 28, Rue St. Dominique, Paris 7, France.

"Plastics Progress in Japan" is a statistical summary of production and foreign trade. It runs six mimeographed pages. It may be obtained from R. Sekido, Sekido Scientific Research, Tomio, Nava, Japan.

"Applications of Statistical Quality Control Methods in the Plastics Industry" by T. V. Subba Rao, of Seivri, Bombay reaches our desk as an 18 page reprint from Paintindia, Vol. 5, Nos. 9 and 10. Of most interest to SPE members is that most of the references are to the SQC series recently published in the SPE Journal under the guidance of L. M. Debing. We're always glad to hear from our friends in India. Thanks, Mr. Rao.

THE INJECTION molderscope

By A. R. Morse
President, Injection Molder's Supply Co.

The Injection Molderscope solicits articles on any phase of injection molding from anyone who has ideas they want aired. We want stimulating articles and comments from anyone that can be adapted for publication. So let us hear from you — on machinery, on powders, on molds — it is your chance to be heard.

WATER COSTS

Hot humid weather always brings up two paramount problems for the injection molder: first, the need for adequate oven capacity to dry the plastic material; and second, water costs. Particularly in the case of older, full-hydraulic machines, cooling coils are often inadequate when water temperature rises. During the hot months, in almost every case, water lines are usually run wide open in every injection plant with a marked increase in water costs.

There are several ways to meet rising water costs. Perhaps the first and least expensive method is to add an extra and larger Ross Oil Cooler to the one supplied as standard equipment. This squeezes a few more degrees of heat into the water and sometimes permits the water flow rate to be reduced.

A few plants have experimented with refrigeration, but the costs of installing and maintaining refrigeration systems, plus the cost of the extra water needed to cool the chilling units themselves, have made these installations of dubious value. Furthermore, pipes sweat and with refrigeration all overhead pipes must be wrapped. One of the big problems with refrigeration is that we cannot tell the refrigeration experts exactly how many BTU's need to be dissipated.

To the best of my knowledge it is impossible to calculate from all the various press specifications just what percent of their HP output is translated into heat. Also, as machines age and pumps wear, the amount of power converted into heat increases rather sharply. Thus changing conditions in the molding plant, new and larger molds, addition of bigger presses, plunger cooling, all upset the best estimates of how much waste heat is actually generated in any given injection plant.

The most successful method of meeting high water costs to date has been to use cooling towers and recirculating systems such as are available from Niagara Blower Co., Acme Industries Inc., and the Marley Co., whose Aqua Towers are made in Kansas City. These systems have two minor disadvantages: first, they are large and bulky, and require a good deal of room; and second, they operate on the wet bulb principle which relates the water temperature to the ambient air temperature. In other words, when it's 100° outside, your circulating water will run only about 7° to 10° cooler than the ambient temperature, with the evaporative rate and efficiency varying slightly depending on the installation details and the relative humidity. Apart from their physical size, if you have a unit of sufficient capacity, performance is excellent and savings in water are clear cut when using these evaporative systems.

A Marley Aqua Tower at Vlchek Tool Co., Plastic Division, Middlefield Ohio, takes care of 12 large presses and an extruder, and has virtually operated itself for two years, handling all their requirements through two hot summers. Acme Evaporators at Wolverine Plastics and Michigan Panelyte were recently featured in the **Acme News Record.** At Michigan Panelyte two Acme Towers cool 46 molding machines and have cut water consumption from 14½ million gallons to 3½ million, and reduced water costs from $2300 to $575 annually.

About the only mistake one could make in installing evaporative coolers would be to underestimate either maximum summer time requirements, or fail to estimate all one's marginal cooling requirements like molds, plungers, and the like, and also to fail to plan for normal plant expansion. The initial cost of an oversize evaporator and adequate size pipe lines is small compared to the expense incurred if the unit purchased soon proves to be undersized. The units are virtually maintenance free, and the operating costs consist only of a trickle of make-up water automatically fed into the circuit to compensate for evaporation losses, and the power to operate the circulating pumps and blower fans. Certainly those plants with these systems are well satisfied and their water costs are sharply lower than most plants on straight city water. Our inefficiency in water use in the injection industry is extremely high and costly, and more of these condenser systems should be used to control water waste and water cost.

It is important to note that water pipe size must be refigured when using these systems, as the volume of water now handled has to be increased to compensate for the fact that the water being circulated is going to run at a considerably higher normal temperature than city or well water. Without larger water lines, an evaporative system could fail to perform satisfactorily, and the expense of repiping should definitely be figured in estimating installation costs.

Some Pertinent Expressions

Wayne Pribble

Dear Friends:

I want to have a few words with you on the subject of COMPROMISING. From somewhere, we have developed a national attitude that we must compromise with any suggestion that fails to fit in with our ideas of right and wrong. A Wall Street Journal philosopher quoted a lady as saying, "I am always ready to compromise—except when I know I am right." Consideration of this thought will show two different meanings. The first and, of course, most ideal meaning is that when we are on the side of right—there **should** be no compromising. The other, and most often used meaning, is that we feel the other person should compromise or meet us half-way even though we know he is right and we are wrong.

Let us not forget that we have the very best of yard sticks for measuring "right" or "wrong." The plumb line of the Holy Scriptures does not change nor allow compromises to fit our special wants and wishes.

Yours for Better Living with Plastics,

Wayne I. Pribble

AROUND THE WORLD

AUSTRALIA

AUSTRALIAN PLASTICS

Vol. 12, No. 126, Jan., 1956

Abstracter: Albert Lightbody

LARGEST FLAG POLE TO GET PLASTIC COAT, p. 30

The Canadian Government recently gave a flag pole, a Douglas Fir from British Columbia, to the people of Australia. One hundred thirty-two (132) feet long and weighing six (6) tons, this huge pole will receive a chemical preservative treatment in a polyethylene envelope holding 5,000 gallons of chemicals.

FRANCE

INDUSTRIE DES PLASTIQUES MODERNE

Vol. 8, Nos. 4 and 5

Abstracter: Hans Mayer

"KRALASTIC" TUBING FOR HYDROCARBONS, NATURAL GAS, SALT WATER, AND CHEMICAL PRODUCTS

The material resulting from the copolymerization of acrylonitrile and styrene (Kralastic) can be extruded and injection molded into the form of rigid tubing which due to its properties is suitable for use in the natural gas and petro-chemical industry. Sizes have been standardized to follow the Iron Pipe and Solvent Weld Pipe normes. The question of pressure resistance is discussed. Possible applications and methods of installation are described.

THE PHENOLICS, M. Suprin

The phenoplastics count amongst the first industrial plastic materials. Their production rise has been great but is slowing down or has come to a standstill due to the arrival of new members of the plastic family. The author discusses the particular qualities of phenoplastics which, in his opinion, guarantee them a permanent place in the field of molding materials, industrial resins, the lumber industry, etc.

EDUCATION IN PLASTICS, S. Guillard

Under government supervision schools have been formed to produce professional workers. By this is meant that adults without college training are prepared in courses of not less than six months but not longer than one year to acquire professional skills in specified industries. Such schools can be conducted on company or industry levels. The course of studies in one of these schools is described. It comprises besides practical work industrial designing, calculation, reading of prints, and plastic chemistry. The program is being extended to embrace all phases of the industry.

GERMANY

KUNSTSTOFFE

April, 1956

Abstracter: Anne Schwend

DETERMINING THE HARDNESS OF PLASTICS, by Walter Gohl

Thorough comparative tests of balls, pyramids and cones proved that a 5 mm ball represents the best indentation body for determining the hardness of plastics. The indentation depth after 60 sec. of loading is measured. The test load is chosen in such a manner that the indentation depth will remain within the limits of $.15 \leq t \leq .35$. Initial loading is effected with 1 kilo. Equipment needed for such tests as well as evaluation of results are discussed. This article is meant as contribution for the standardization of a method for determining the hardness of plastics that are used as carrying constructional elements and for many other purposes.

DETERMINATION OF GAS PERMEABILITY OF PLASTIC FILMS, by Werner Schrufer

Experiments to stipulate the sensitivity, accuracy of measurements and lowest possible limit for measuring of devices for the determination of gas permeability, indicating a change in pressure or volume by displacement of a mercury thread, resulted in conformity of measured values with those calculated for three apparatuses of different dimensions. Essential result of equations: the accuracy of measurement depends on the measuring volume of the apparatus. The permeability of very dense films can only be satisfactorily measured in case the measuring volume is kept correspondingly small.

LOSS IN SUBSTANCE BY ORGANIC INSULATORS, by C. Reimer

The evaluation of the reduction in weight upon determination of losses in substance by sundry organic insulating materials showed that in all cases except those where much oxygen had been taken up, the curves obtained were subject to exponential functions depending on time. The initial relatively brief part of the weight-loss-curve stands for the evaporation of moisture and monomers present in the compounds, of plasticizers, solvent residues and products of separation from condensation, the second part shows the percentage of low molecular substance separated by thermal and oxidizing influences. Thermal influence over long periods, however, does not produce a constant factor of change for matter. Losses in substance give a good survey over the thermal stability of organic compounds; however, the thermal stability over long periods for practical use of insulating materials has to take into consideration the irreversible thermal properties in particular.

CHLORINATED PHENOLIC ETHERS, by O. Pesta and F. Sinwel

The properties of a tetrachlorodibutoxybenzol (80-85%) and pentachloro-butoxybenzol (15-20%) compound, called "Mollan C" and produced by Oesterreichische Stickstoffwerke, show particular resistance against chemicals, extending effects for the stabilization of PVC pastes at normal temperatures which convert into plasticizing effects when the temperature rises above 110-120°C., and good compatibility with nitrocellulose, chlorinated caoutchouc for plasticizing of light-fast lacquers and paint materials. High chlorine content of

Mollan C reduces flammability of plasticized PVC to a minimum. No advantages are offered for film production, while application in the foodstuff industry is inadvisable.

HOW TO REDUCE MANUFACTURING COSTS OF INJECTION MOLDS, Hans Gastrow

Adequate planning and design drawings avoid unnecessary extra cost, permit splitting up of work among workers and, hence, reduction of delivery terms, plus better coordination of customer's wishes with feasibility of production.

EXTRUSION DIES: DIES FOR PIPES AND CROSS-HEADS (Part I), G. Schenkel

Different design possibilities and a comparison of the advantages and disadvantages of older and modern designs of pipe extrusion dies and oblique as well as cross-heads for wire coating are discussed whereby the problem of pressure equalization for the latter extrusion dies finds particular consideration.

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GREAT BRITAIN

PLASTICS

January, 1956

Abstracter: Alfred T. Rexer

EXTRUSION OF CLEAR P.V.C. FILM

This article describes the production and properties of commercially available clear p.v.c. film up to widths of 36 in. as produced by the extrusion process. The apparatus employed is in general principle similar to that used for polyethylene. The difficulties mainly arise from the fact that the die temperatures required are those at which thermal decomposition of the material is rapid and much more complex and closely controlled compounding techniques are called for.

PLASTICS IN THE SERVICE OF MAN

A three page pictorial review of high-quality units molded or otherwise fabricated for the furniture field.

P.V.C. EXTRUSION COMPOUNDS, by H. D. Brett

First read as a paper before the Swedish Plastics Federation, this article discusses the relationship between customer and compounder in the p.v.c. field followed by a step-by-step explanation of the technique and raw materials used in the compounding of various p.v.c. formulations.

THE PROPERTIES AND TESTING OF PLASTICS MATERIALS—Part 2 (Cont.), by A. E. Lever and J. Rhys

Adhesion, Bond Strength, Ageing, and Friction testing are covered in this installment. Methods of testing and a bibliography are given.

BARREL FINISHING METHODS FOR PLASTICS, by E. C. Emslie

A three page article discusses the method of finishing plastics which has made the greatest strides in the last few years.

February, 1956

OPTICAL LENSES IN PLASTICS

This article describes, with illustrations, the forming, grinding, and polishing of acrylic sheet in the production of contact and micro lenses.

PLASTICS IN THE SERVICE OF MAN

A pictorial review of high-quality units molded or otherwise fabricated for use in the agriculture and horticulture field.

VACUUM FORMING AND INJECTION MOLDING Part I

This five page article gives the results of an inquiry into the costs of the two methods. Several charts are given. The conclusions arrived at are as follows:

(1) Considerable difference of opinion amongst injection molders on the cost or type of tool warranted by orders.

(2) Actual running costs on vacuum-forming machines are still of a speculative nature. Tool cost differences are not so apparent in view of the total low costs involved.

(3) The figure beyond which it will be cheaper to injection mold is controlled primarily by the cost of the sheet material.

(4) Running, finishing, and other sundry costs on vacuum forming are approximately balanced by the running costs of an injection molding machine.

(5) Vacuum forming of small objects in thin material is the best economic proposition for vacuum forming.

(6) It is still cheaper to injection mold large objects than it is to vacuum form them.

THE PROPERTIES AND TESTING OF PLASTICS MATERIALS—Part 3, by A. E. Lever and J. Rhys

Low Temperature, Softening Point, and Flammability testing are covered in this installment. Methods of testing and a bibliography are given.

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BRITISH PLASTICS

Vol. 29, March, 1956

Abstracter: Evert A. Mol

ELASTROSTATIC CHARGES ON POLYVINYL CHLORIDE By B. Dudley Sully. Page 103

Electro static charges on plastics are sometimes troublesome. For instance, in molding where the molded part will quickly pick-up dust and in hospitals or theaters where the flooring for safety must be electrically conductive. A U. S. recommendation is that the floor should have a surface resistance of not more than 1 megohm between 2, 2-½" electrodes, three feet apart. This is a borderline demand for pvc flooring. Another place where static electricity can be dangerous is in powders. For instance, a dry non-metallic powder passing through a bronze sieve can accumulate a potential of 15000 volts, enough to set up dust explosions under certain conditions. The article goes on to describe various types of apparatus for the detection of electric charges and their application for the assessment of the electro-static properties of plastics. Naturally the available anti-static agents are mentioned. These anti-static agents mostly belong to one of these four classes:

(1) Nitrogen compounds such as long-chain amines.

(2) Sulphonic acids and sulphonates.

(3) Polyglycols and derivatives.

(4) Polyhydric alcohols and derivatives.

The article ends with a short discussion of the volume resistivity of pvc as influenced by plasticizers and fillers.

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UNITED STATES

RUBBER AGE

April, 1956

Abstracter: James Harrington

THE MEASUREMENT OF VOLUME RESISTIVITY OF PLASTICIZED POLYVINYL CHLORIDE, by C. E. Balmer and R. F. Conyne, pp. 105-108

The authors describe the development of a new test procedure for determining the volume resistivity of compression molded slabs of plasticized PVC. This procedure correlated well with results from insulation resistance tests while having the advantage of requiring less cost and material than the latter test in the preparation of specimens.

SPEAKING OF EXTRUSION

Edited by **R. D. Sackett**
Technical Service Associate
Monsanto Chemical Company
Springfield, Massachusetts

Single and Double Screw Extruders

E. Gaspar

Projectile and Engineering Co., Ltd.

During the period which preceded the last war, the most widely used thermoplastic material for extrusion purposes was P.V.C. At that stage in the development of the plastics industry, the extruder was used merely as a means to give the finished product its final shape. All the requisite mixing and heating were carried out on heavy rolling and kneading equipment which had to be adjacent to the extrusion machine. This arrangement made the whole process relatively expensive in view of the high capital expenditure required.

In the late thirties supplies of P.V.C. material more or less in the form in which it is now sold, became available and allowed the extruder to be divorced from the expensive machinery required for the complete process. This change, however, was not an unmixed blessing and difficulties were experienced in feeding many of the premixes then available.

Because of the tendency of P.V.C. materials to degrade if subjected to heat and pressure for undue lengths of time, it is important to extrude these materials on a machine in which slip was reduced to an absolute minimum.

The twin screw extruder, which acts as a positive pump and delivers a melt almost regardless of the consistency of the material fed to it, was developed primarily because of these feeding problems. Since this time, a range of multi-screw machines has been developed, whose performance in many respects rivals that of single screw machines. Both types of machine have their advantages and disadvantages and it is worth while to examine the basic requirements for an extruder and the manner in which the two types of machine carry out these functions in order to distinguish between the relative merits of the two systems.

COMPARISON BETWEEN SINGLE AND DOUBLE SCREW EXTRUDERS

Basic Requirements

The purpose of all types of plastics extruders is threefold. First, to raise the temperature of the plastics material to a suitable level at which it can be formed. Second, to mix the material as thoroughly as possible and ensure homogeneity of consistency and of temperature distribution and, third, to compact and convey the heated and mixed material and to force it through a die orifice.

Single Screw Machine

In the single screw machine heating is carried out partly by conducted heat and partly by the energy which is put into the material by shear in the screw flights. The proportions of the total energy input contributed by each of these mechanisms has not so far been very clearly defined. At this stage it is sufficient to say that under normal extruding conditions with the majority of thermoplastic materials, by far the greater part of the energy input to the plastics material comes from the screw in mechanical work. The external heating system, therefore, merely maintains the temperature of the barrel wall, compensates for radiation losses and heats the machine for the initial start up.

The mixing is carried out by means of the shearing action in the material and can take place along the whole helix of the screw. The fact that a velocity gradient exists across the screw lands means that layers of material are displaced relative to each other and mixing therefore takes place. There is ample theoretical and practical evidence available to show that these velocity gradients exist not only between the barrel wall and the root diameter of the screw, but also in a plane perpendicular to this across the flight profile. This transverse flow, although it does not contribute to the output of the extruder, has been shown to have a tremendous influence on the mixing properties of a machine.

The compacting and conveying of the material against the back pressure engendered by the die is accomplished by two mechanisms. The first and most powerful is the thrust from the granular material in the feed end of the screw and the second is the drag flow in the viscous material in the die end of the machine.

Multi-Screw Machine

In a twin or multi-screw machine the heating of the material is carried out almost entirely by conduction. The screw flights are deep and narrow, thus a high rate of shear is not possible at normal screw speeds and, consequently, very little heat is generated by shear. Furthermore, since the mechanism of conduction is time dependent and the material must of necessity remain in the extruder barrel for a certain minimum period, the screw speed has a definite upper limit.

Mixing in this type of machine is accomplished firstly by tumbling the granules and, secondly, by the wiping and shearing action of the screws on the viscous material. Because of certain mechanical limitations, material has to be metered into a multi-screw machine to ensure that the screw flights are never completely filled. This enables tumbling of the granules to take place, but the material in its path through the machine is confined to a series of discrete C-shaped cavities and mixing can only take place within these cavities.

The conveying and compacting is achieved by the positive pump action of the intermeshing screws. Whatever material is fed to the screws is inevitably delivered to the die of the machine and the resistance offered to the flow of the material by the breaker plate system and die causes a pressure build-up in exactly the same manner as in the single screw machine.

RELATIVE MERITS

(a) As far as heating of the material is concerned, the designer of the single screw extruder is in a position to impart heat by mechanical shear to an extent which is desirable for the particular material. This method obviates the necessity of temperature gradients within the material and ensures better quality of extrudate.

(b) As far as mixing is concerned, it appears that no large scale mixing can take place in a twin screw machine because of the discrete packets of the material formed by the intermeshing screws. On the other hand, the continuous

(Please turn to page 47)

This material was abstracted from a paper presented at the 12th Annual SPE Technical Conference.

Edited by

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Cleveland-Akron

Three-Member Panel Follows Theme of 'Elastomeric Vinyls'

R. M. Hershey

"Elastomeric Vinyls" was the theme of the April 9 dinner meeting of the Cleveland - Akron SPE Section. A record attendance of 120 members and guests attended the meeting which was held at the Spanish Tavern, Brecksville, Ohio.

A three member panel consisting of R. A. Mansfield, Technical Superintendent, Marietta Division, B. F. Goodrich Chemical Co.; R. M. Hershey, Senior Engineer, Hoover Company; and D. F. Siddall, Research Director, U. S. Stoneware, discussed "Extrusion of Vinyls," "Injection Molding of Vinyls," and "Toxicity Considerations of Vinyls" respectively.

R. A. Mansfield, the first speaker, reviewed the properties of elastomeric vinyls which make them especially interesting for extrusion applications and described several current applications.

Outstanding among the properties of the vinyls are the brilliant colors and the ease of maintenance. High quality PVC compounds are long wearing and show outstanding abrasion and scuff resistance. Almost any degree of flexibility can be obtained and flexing life is very good at normal temperatures. Resistance to indentation and recovery from deformation are available. Resistance to breakage, rupture or tearing also can be obtained.

Vinyl extruded parts stand up well under normal weather conditions and do not craze excessively. A high gloss can be obtained if desired and the extruded parts are smooth and pleasant feeling to the hand. Vinyls are also oil and grease resistant.

Vinyls have largely replaced rubber in refrigerator gasketing. Although very cold temperatures tend to limit PVC applications, compounds can readily be designed to withstand the required low temperature flexibility for the refrigerator gasket. Plasticizers must be selected with care in order to avoid migration problems since the vinyl is often in contact with polystyrene in refrigerators.

Gaskets for autos, for windows, and for sealing buildings to close cracks and crevices were cited as high volume PVC extrusion applications. Migration, lacquer softening, plasticizer exudation, and weathering were all mentioned as being especially important in respect to auto weather stripping.

A greatly expanded future for elastomeric vinyl extrusions was predicted by Mr. Mansfield.

R. M. Hershey discussed the problems encountered in the molding of elastomeric vinyl materials and reviewed some of the techniques which have proven successful in solving the problems. Mr. Hershey emphasized that although different molding techniques are required for the elastomeric vinyls, the vinyls are really not much harder to mold than styrene or the cellulosics. Due to improvements in both molding material and equipment, the burnt cylinders which plagued early molders are a rarity today with most large vinyl molders.

Practically all of the problems encountered in the molding of the vinyls stem from the poor thermal stability and low heat conductivity which make uniform plasticization of the materials difficult to obtain.

Most molders restrict the material flow in the nozzle or gates and use the frictional heat obtained to complete the plasticization of the vinyl material. Mr. Hershey said that vinyl gating depended to a great extent upon the particular part under consideration and usually differed from part to part. In general, the speakers company had obtained best results with a gate .031 inches in diameter and .062 inches in land length. The material should flow onto an obstruction after leaving the restricted gate. Full round and generous runners were recommended.

Cylinder derating has been found to be essential on most standard molding machines if a good surface finish is desired on the molded part. Cylinder streamlining and plating have been found to be very helpful. Heated torpedoes are preferred to cold torpedoes. Cylinder temperatures in the neighborhood of 350-400 F are usually used with the vinyls.

The Jackson and Church screw preplasticizing injection molding machine has been found to be very satisfactory for vinyl molding. Vinyl dry blends can be molded on the machine with a considerable savings in raw material costs. Vinyl parts molded on the machine have been found to be very free of strains and can be molded using short cycles.

Despite higher raw material costs, vinyl moldings have often been found to be cheaper than rubber moldings due to the shorter molding cycles. Parts weighing as much as ten ounces have been converted from rubber to vinyl with an appreciable cost savings. Several vinyl parts which were formerly molded of rubber were exhibited.

Samples representing different applications of molded vinyls in household appliances were shown. Other applications of molded vinyls such as toys and luggage binding were also reviewed. Mr. Hershey predicted that the use of elastomeric vinyl for injection molding would increase sharply in the future as designers become more familiar with the properties of the material. The third speaker, Don Siddall, discussed problems encountered in preparing non-toxic vinyl extrusions for food and medical usage.

The third speaker, D. F. Siddall entitled his talk "The Vinyls-Variety, Virtues, and Vices." The talk was a very interesting and humorous discussion of the problems encountered in preparing nontoxic vinyl extrusions for food and medical usage.

The importance of careful selection of each ingredient in the vinyl compound was emphasized. Constant checks for the presence of lead and other contaminants is a necessity. Due to the legal difficulties which could conceivably arise manufacturers of compounding ingredients can make no warranties in respect to non-toxicity of the ingredients and the responsibility for non-toxicity is up to the manufacturer of the extruded or molded item.

The speaker reviewed the federal laws relating to toxicity in connection with food applications.

Five new members were welcomed to the Section at the meeting. They were Basil E. Beckford, National Rubber Machinery Company; Edward G. Bobalek, Case Institute of Technology; R. C. Seanor, Adamson United Company; Richard D. Fredecker, International Molded Plastics; and Donald

W. Williams, Lester Phoenix, Inc.

The chairman of the golf committee, J. R. Jones, Clairmont Pigments, has announced that the annual Golf Outing will be held on Friday June 22 at the Sleepy Hollow Golf Club in Brecksville.

Following the talks the three speakers formed a panel to discuss "Vinyls." Interest in the meeting was very high and the question and answer period was very lively and extended.

Eastern New England

Future Markets For Plastics Are Analyzed

Alfred I. Simon

A joint meeting of the S.P.E. Eastern New England Section and the S.P.I. Boston-Providence Section was held on May 17, 1956 at the Andover Country Club, Andover, Massachusetts. Approximately 150 members and guests attended.

After dinner, a panel discussion on "Future Markets for Plastics" was held. The moderator was George P. Kovach of the Foster Grant Company. The first speaker was John F. Murphy of Monsanto Chemical Company speaking on "Plastics for Agriculture." Some of the uses for plastics mentioned were: silo covers, soil fumigation, artificial irrigation utilizing plastic pipe lines in irrigation ditches, greenhouse usage to control sunlight, mulching applications and even protection of newborn lambs. Among the advantages cited were increased protectivity, improvement of working conditions and cost reduction. Special plasticizers must be used in vinyl-chlorides to resist silage acids, ultraviolet exposure, weathering and low temperatures.

The next speaker was Professor A. G. H. Dietz of M.I.T. who discussed the application of plastics in building and plastics for future trends. He cited such non-structural application as flooring and wall covering. This, he said, is the largest single use of plastics in building. Among the notes of interest were: 150 million pounds of plastics for adhesives, 500 million pounds of plastics for coatings. Among the adhesive applications are phenolics and urea for the bonding of plywood.

Vinyl wall covering bonded to plaster or wood gives very good abrasion resistance. Polystyrene simulates ceramic tiles and is easily bonded to walls, but allowance must be made for expansion and contraction due to temperature changes. Flexible polyethylene has been used in place of copper tubing for heating in concrete flooring. Foam has been utilized for perimeter insulation. Plastic film has supplied a vapor seal in poured concrete floors. Some work has been done with stressed skins both of plastic and plywood with honeycomb cores for wall structures. Professor Dietz then discussed some semi-structural units such as the geodesic 55 foot glass laminate radar domes to withstand 150 miles per hour winds. These domes have neoprene gaskets and nylon bolts. Slides were shown on all of the above mentioned plastic uses in building including Monsanto's House of Tomorrow wherein the center room is the main room with other rooms surrounding it being supported in a cantilever fashion. Some of the problems involving the utilization of plastics in building are: the flammability and the burning toxic properties of plastic materials. However, Los Angeles and San Francisco building codes are allowing plastics under specified conditions.

The next speaker was Leroy Darling of Sperry Gyroscope Company. He discussed the utilization of polymerized resins in the design and application of electronic components. He pointed out that polyester resins replaced the old time wax and hot melt resin materials for potting electronic components. These high-temperature potting materials had such mediocre electrical properties that they were not suitable for embedding the high frequency, high impedance circuits used in many electronic components. Polyesters on the other hand possess very good electronic properties and can be modified to obtain various properties by the addition of other monomers, fillers and plasticizers. Wherever severe temperatures and strength requirements have occurred, polyesters have been replaced by epoxy resins. Mr. Darling then discussed the method of embedding electronic units such as transformers, amplifiers, rectifiers and the like. Among the benefits cited for the use of these embeddment techniques are ruggedness, shock proofing, hermetic sealing, moisture proofing, elimination of mountings, stabilization of electronic operation, miniaturization and the utilization of plug-in assemblies. He pointed out the need for liaison between the designer and the plastics engineer early in the design stage of embedded circuits.

The fourth speaker of the evening was Robert Lowry of the Cryovac Company. Mr. Lowry covered the principal materials of packaging especially for food, drugs, cosmetics and metals. First plastic used for packaging was cellophane over thirty years ago. This contributed sanitation and visibility. Mr. Lowry described his company's product "Cryovac" which is based on saran. This material shrinks 30 to 60 per cent when immersed in hot water. It has low oxygen and moisture transmission. This film properly used extends storage life of food by decreasing the bacterial growth. It also prevents localized freezer burns because of the lack of air pockets due to the tight fit around the food products. Because of the shrinkage of Cryovac, odd shapes can easily be packaged. Among the other types of packaging units presently being used are polyethylene-cellophane laminates, polyethylene saran and mylar. Saran and polyethylene can be coated onto mylar to increase resistance to moisture vapor transmission. Three basic fundamentals of present and future packing are: 1, protection; 2, appearance; and 3, convenience. These are the basic requirements for any successful packaging units. Among other types of plastic packaging on the market today are squeeze bottles, plastic tubes, drug packaging, coin dispensing machines, aerosol bombs, protection of new clothing, vacuum-formed hardware packages, foam for shipping and paint capsules for coloring. Mr. Lowry finished up by citing an example of the time and cost required to have new materials approved by the U.S. Food and Drugs Department: $80,000 and a two year rat test was necessary to determine whether a plasticizer used in plastic film for packaging was acceptable to this department.

The meeting closed with a 16 mm. sound film in color entitled "Pipe Lines to the Future." Robert Bell of Republic Steel Corporation mentioned that this was the first showing of the film in the United States. This picture shows the various uses of plastic pipe in industry, on the farm and at home.

Pioneer Valley

Chemical Structure Of Polymers Is Discussed

John T. Moore

The regular May meeting of the Pioneer Valley Section of the Society of Plastics Engineers, Inc. was held on May 10, 1956 at Wachusett Country Club, West Boylston, Mass. In the absence of the president and vice-president, the secretary, Mr. John Moore, presided at the meeting. Attendance was 100 members and guests.

Mr. Chafetz introduced the speaker, Mr. Robert McCarthy of Monsanto Chemical Company, Plastics Division.

Mr. McCarthy gave a talk on the chemical structure of various polymers in the plastics industry. This he followed by showing a very interesting color movie entitled "The World That Nature Forgot," produced for Monsanto.

New vice-president of the W.N.E. Section, Raymond A. Mazur, second from left, accepts gift from outgoing president Arthur W. Logozzo, in name of new president, Lewis Gustafson. Wesley S. Larson, left, and Lawrence W. Freeman, right, new directors.

Western New England

Lewis Gustafson Elected President

C. P. O'Donnell

The Western New England Section's final educational meeting prior to the summer hiatus featured two speakers on reinforced plastics, and introduced the Section's newly elected officers to the group. Held in the Terrace Dining Room of Bradley Field on May 2, under the direction of Technical Chairman Raymond Mazur, Plastics & Resins Division, American Cyanamid Co., the meeting started with a talk on the various molding methods used in the reinforced plastics industry.

The speaker, Mr. Clare E. Bacon, Manager Technical Sales Service for Reinforced Plastics Division, Owens-Corning Fiberglas Corp., discussed bag molding; the Marco Method; continuous laminating and extrusion; pre-forms in a plenum chamber operation; wet slurry; die, compression, transfer and injection molding; and then extensively covered the manufacture of Fiberglas reinforced panels.

Mr. Bacon made liberal use of slides to amplify upon his talk and to point up the various processes. He then introduced the next speaker, Mr. A. J. Wiltshire, Chief Engineer Fiberglas Division, Apex Electrical Mfg. Co., Cleveland, Ohio, who covered a particular, and different, reinforced plastics problem.

The problem, fabrication of fibreglass and epoxy resin pressure bottles for starting jet aircraft, was given to Apex in May, 1951. This bottle, to replace a steel bottle weighing 32 pounds, among other specifications had to weigh 16 pounds, have a proof pressure of 5000 P.S.I., and to be shatter proof when hit with .50 caliber armor piercing bullets while loaded to 3000 P.S.I.

It took over two years of intensive research before Apex started preliminary production, and they have produced the bottles ever since. Apex's first approach was to use wood working-models to test various possibilities for windings, working in conjunction with the Case Institute of Technology under the direction of Dr. H. R. Nara. Using the facts gathered from the wooden ball windings the Apex engineers were able to construct the necessary production equipment.

Mr. Wiltshire then discussed the advantages and limitations of working with fibre-glass, and various core materials tested. Rubber was finally used as the only solution to the large stresses put upon the cores.

An interesting point brought out by the speaker was the careful quality control exercised during fabrication of the bottles. All steps and materials are controlled. Four per cent of all bottles are checked to destruction — every 25th and 75th bottle being burst, every 50th and 100th bottle being cycled 10,000 cycles and burst. Gunfire tests show no tear quality to the laminate, which uses 17,000 miles of fibre-glass .00032" filament in each winding.

At the conclusion of Mr. Wiltshire's talk the two speakers combined forces to face a barrage of questions during the discussion period. During this period the epoxy toxicity hazard in winding was underlined, and the Apex knowledge in combating the problem was offered to all interested inquirers.

Following the speakers, these newly-elected 1956-1957 officers were presented:

President — Lewis Gustafson, Development Engineer, Prophylactic Brush Co.

Vice President — Raymond Mazur, Sales Engineer, American Cyanamid Co., Plastics and Resins Division.

Treasurer — Richard Plichta, Supt. Plastics Dept., Noma Lites.

Directors—Wesley Larson, Plastics Design Engineer, De Bell & Richardson; **Lawrence Freeman,** Plastics Research & Development, Plax Corp.

Arthur Logozzo, President of Nutmeg Chrome, and retiring W.N.E. Section President, presented the new officers and directors.

Southern California

Chemistry of Polyurethanes

John A. Stahmann

The June 7th technical program of the Southern California Section of the S.P.E. was held at Scully's Restaurant. The report on "Chemistry and Applications of Polyurethanes" was presented by Mr. Don MacGregor of Nopco Chemical Company and Mr. Andy Mitchell of duPont. One hundred and twenty people attended.

According to the speakers, the first isocyanate was synthesized by Westz in 1849, but activity in this field was delayed until the 1930's, when the value of polyisocyanates in polymerization reactions with active hydrogen groups was recognized. Several methods of synthesis have been developed, but that of phosgenation of an amine or its salt is the most economic. The structure of the isocyanates may be related to their use as adhesives, cross-linking agents, and foamed rubbers.

The inhalation toxicity problem can be prevented by knowing the products and their hazards and by using the recommended precautions. A limitation of one-tenth part per million has been set for continuous exposure to fumes. This is a lower concentration than detectable by odor, so a quantitative test should be developed for work areas.

The commercial value of the diisocyanates is due to their extreme reactivity with water, glycols, alcohols, carboxylic acids, amines, and other sources of active hydrogen. In practice, these reactions do not produce simple products, but mixtures of cross-linked polymers. The reactivity is influenced by steric hindrance, the activity of substituted groups, and the use of catalysts.

In making cellular products, polyureas are likely to be brittle and powdery, while the products derived from hydroxylated materials such as alkyd resins and diisocyanates have better physical properties. Consequently, the latter are reacted in the presence of water and excess NCO groups to give the desired amount of gas. The increased number of unethane hydrogens in low molecular weight hydroxy compounds gives harder and tougher products.

Softer products are produced by keeping the distance between OH groups large and reducing the number of urethane hydrogens.

Foams are made by two procedures. The "one-shot" method blends alkyd resin, water, catalyst, and emulsifier with the diisocyanate. The "prepolymer" method reacts the alkyd resin with an excess of of diisocyanate prior to use. While the one-shot method has the advantage of simplicity, the prepolymer technique provides better control and reduces the toxicity problem. Methods of production also depend upon the requirements of the final product, most systems having to be tailor-made for the customer. Closed cell types are hard to control and are more costly.

The density of foams may be varied considerably within the limitations imposed by viscosity. While the resilient foams have a higher load-bearing capacity and tensile strength than natural rubber-G.R.S. foams, they are inferior in compression set and elongation. They have good resistance to weathering and oils, but prolonged exposure to water vapor is deleterious.

Solid polyurethane rubbers may be fabricated much as in conventional rubber techniques, but following the additional diisocyanate to vulcanize, final processing must be rapid. These rubbers are outstanding in abrasion resistance.

In coatings, diisocyanates improve adhesion and toughness while reducing drying time. Use of a two-component system and darkening upon exposure to light represent disadvantages. In adhesives for elastomers, a volatile solvent is used, followed by a rubber cement vulcanization process.

The techniques of foaming such commercial articles as pipe insulation, instrument cases, and radomes, have been advanced by the work of suppliers. Other articles include stator blades, helmets, and building panels. In their work, the selection of a release agent has proven to be difficult, since there is no universal or foolproof material for this use.

Central Indiana

Mold, Temperature Control Discussed

David D. James

On Tuesday, May 22, the regular monthly meeting of the Central Indiana Section was held at the Warren Hotel in Indianapolis. The subject of the meeting was "Mold Temperature Control." A panel discussion of the subject was conducted by two highly-qualified men, Mr. Paul West, President of Sterling, Inc., Milwaukee, Wisconsin, and Mr. C. H. Whitlock, of Whitlock Associates, Oak Park, Michigan. Mr. West covered the equipment required for controlling mold temperatures, while Mr. Whitlock discussed the reasons for close control of mold temperature and mold design necessary to obtain it. Everyone present participated in a lively question and answer period following the talks.

Newark

Molder-Moldmaker Relationship Aired

J. R. Bostwick

A goodly crowd of 125 members and guests turned out for the Newark Section meeting on May 9th, featuring a panel discussion on "Molder - Moldmaker Relationships and Responsibilities, Who is Responsible for What." This was the last Section meeting for this spring.

The moderator, who did a fine diplomatic job of moderating, was Mr. E. Keusch of Fiberite Corporation. The molder members of the panel were Messrs. J. O'Brien of Shaw Insulator Company, and H. E. Hasenzahl of Pro-Phy-Lac-Tic Brush Company. Moldmaker members of the panel were Messrs. E. J. Csaszar of Eagle Tool & Machine Company, and J. A. Kavanaugh of Standard Tool Company.

Each panel member gave a short prepared speech. Mr. O'Brien felt that the mold maker's responsibility was chiefly in accuracy of dimensions and adherence to delivery schedule. He also raised such provocative questions as who owns the hob and who dictates the steel used. Mr. Csaszar emphasized the "joint venture" nature of a mold. Molds are not catalogue items but are custom built. He listed such items as design of the part, designation of molding material and shrinkage correction, fitting to the machine, placing of knock-out pins and cooling channels as primarily the molder's responsibility. He listed such items as feasibility, mechanical functioning, conformance to design, good workmanship, finish, and fit at parting lines as primarily the mold maker's responsibility. However, Mr. Csaszar still stressed the joint nature and need for a meeting of minds in the mold design.

Mr. Hasenzahl, when he was not entertaining the audience with his dry humor and anecdotes, dwelt on such problems as delivery schedules and polishing. He was not in favor of testing by the mold maker. Mr. Kavanaugh deplored the general policy of not paying the mold maker until after the mold was completed and in operation. He pointed out that the mold maker was the only one with money tied up. He also held both mold maker and molder to blame for a situation where a mold maker would quote an unrealistic delivery date in order to get a job and it would be accepted as such by a molder who should know better.

A lively question and answer period followed covering all phases of molder and mold maker relationships. It finally had to be cut short because of the lateness of the hour.

SPEaking of Extrusion

(Continued from page 43)

flights of a single screw machine in which the extent of the transverse flow can be controlled by judicious screw design, making mixing possible over a long length.

(c) From the point of view of feeding materials, there is no doubt about the general superiority of the multi-screw system. Material of any form — powder, flakes, granules and even wet mixes — can be fed to such a machine, and due to the positive pump action, the material will be delivered to the die. In the case of the single screw machine, only certain materials, mainly in granular form, can be fed without difficulty. In the case of powder mixes and wet mixes, due to adverse frictional properties, continuous conveying along the screw is not easily achieved and there is a tendency for material to rotate with the screw and not to be conveyed to the die.

How far do the above considerations affect the output of an extruder for a given screw size? In the case of a double screw extruder, the heat input, since it is mainly conducted heat, is time dependent. This will put a limitation on the actual throughput of the material. With a single screw machine, on the other hand, the bulk of the heat is put in by shear. The heat input to the material increases with the screw speed and the rate of working is only limited by the maximum power available to turn the screw.

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TEMPERATURE CONTROL UNITS

Effect of Explosions . . .

(Continued from page 16)

to fracture by shock waves. It is possible that the resin segregated in the tips during molding, and that the incipient spalling at low temperature occurred in this material. From this we may infer that the tire cord phenolic attenuates shock waves at room and elevated temperatures, and to a lesser extent at low temperatures. It is noteworthy that larger charges demolished the material at the site of the explosion and that the shock wave emerging from the disrupted material was too weak to cause spalling, even at low temperatures.

Three orders of merit for the materials tested can be determined from these results:

a. resistance to plastic flow

b. resistance to cracking

c. retention of approximate original shape

Conclusions

As a result of these tests we may conclude that:

a. Plastic deformation under concentrated shock compressive loads is large in polyethylene, polystyrene and cellulose propionate at elevated and room temperatures, and is small in ethyl cellulose and the unmodified phenolics. Plastic deformation is perceptible in the rubber modified phenolics, in the cast polyesters, and in polymethylmethacrylate.

b. The phenomena of multiple spalling, which had been observed in steel, has been observed in the plastics.

c. The resistance to spalling of tire cord phenolics and ethyl cellulose is at least twice that of polymethylmethacrylate and perhaps four times that of the cast polyesters.

d. The attenuation of compressive shock waves by polyethylene at all service temperatures, and by cellulose propionate and polystyrene at elevated temperatures, is considerable. On the other hand, ethyl cellulose and the unmodified phenolics are highly transmissive to shock waves.

e. The retention of shape after spalling is good in the plastics which contain fibrous reinforcements, is fair in the softer thermoplastics and is poor in the cast polyesters.

It is recommended that this test be used to evaluate the behavior under mechanical shocks of other plastics and rubbers, the properties of which are not dependent on the size of the specimen.

It is also recommended that another test be developed which employs small specimens so that the crystalline and orientable polymers may also be evaluated.

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Engineering of Molds . . .

(Continued from page 19)

As previously stated, the molder-mold supplier relationship is a firmly established institution of the plastics industry. This relationship is flexible enough to take on different forms in different places and for that reason some of the points covered here may be considered controversial. The controversies resolve into one single question, however; the question concerning division of responsibility between molder and mold supplier. That is not the subject of this paper, but it can be said that the molder is on firmer ground when he assumes as much responsibility as circumstances permit him to control. Granted, he cannot control the toolmaker's accuracy except by careful selection of suppliers and beforehand warnings on critical dimensions. On vendor-supplied drawings he can hold the mold supplier responsible for the accuracy of the computations. He had better take a personal interest in design considerations and delivery schedules, however, if he is to keep his own customer happy. **No customer was ever calmed by the knowledge that the mold supplier, not the molder, was the cause of non-performance, rejected samples, or late delivery. Only the molder is responsible to his customer.**

In any phase of engineering, job knowledge and exercise of sound judgment are of prime importance. It is only by organization of efforts, however, that effective use of these attributes can be achieved. Organization of efforts is important whether a bridge is being built or a mold is being purchased. In the case of engineering purchased molds, organizing through the use of schedules, breakdowns, and checklists need not be complex or time-consuming. Quite the contrary, a little time invested in this way results in considerable long-range savings in time and effort.

Irradiation of Plastics . . .

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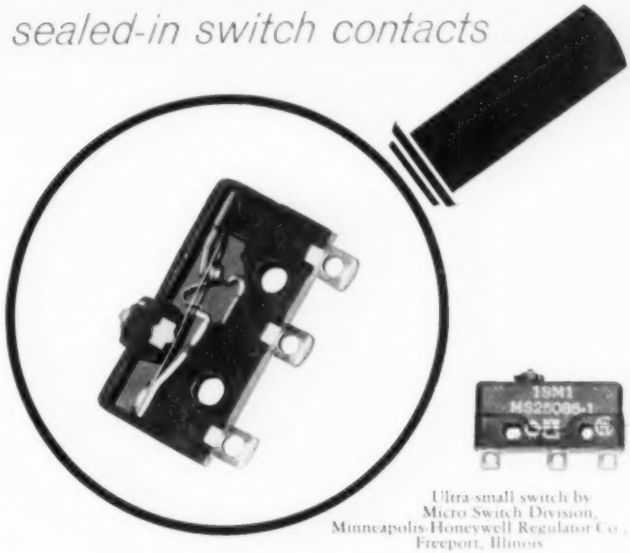

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Book Reviews . . .

(Continued from page 32)

an extensive discussion of the major fields of applications of injection molded articles.

Finally, there are up-to-date statistics on the distribution of some 21,000 injection presses throughout the free world, as well as their capacities, where known, and the number, size, and geographical distribution of the more than 4,000 injection molding firms. The various national societies and their functions are described, and among the usual appendices of Bibliography, Conversion Tables, and Indices, there is a chronological list of about 250 patents, predominantly in the field of injection presses, but also covering basic patents of molds, methods, and materials.

For the injection molding engineer and the press designer, this book fills a long existing gap, and if he is interested in the status of his field, especially in other countries, he should not be too discouraged by the language barrier, since the numerous illustrations will help him overcome this difficulty.

Fred R. Homburger

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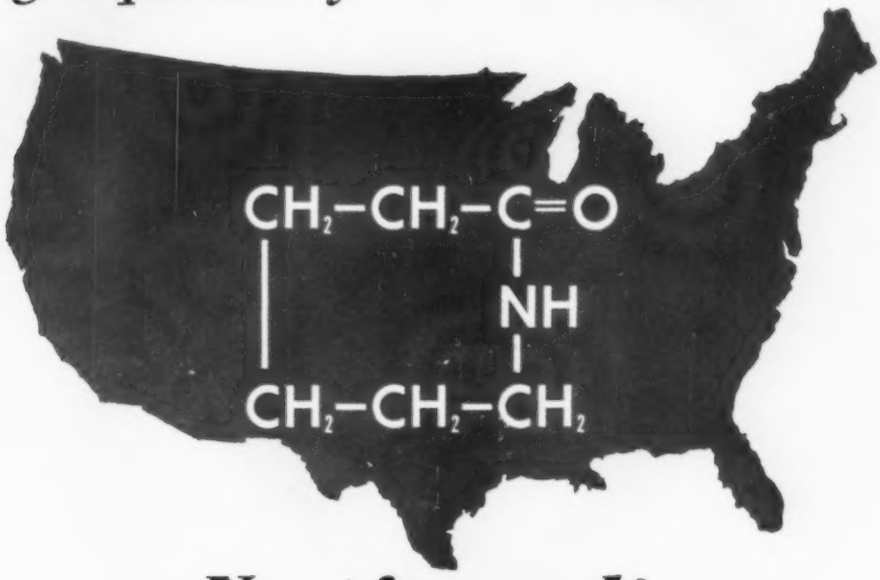

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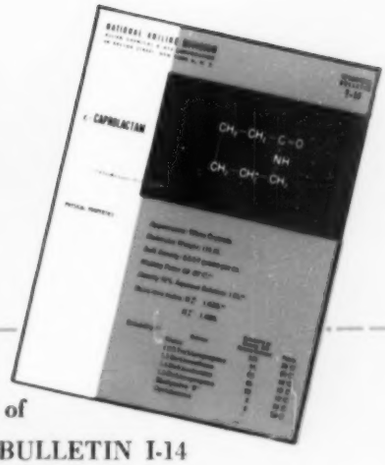

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